UNIVERSITY OF ALBERTA

PEATLAND MANAGEMENT & CONSERVATION IN BOREAL ALBERTA, CANADA

by

Silvie F. Forest ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

in

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ABSTRACT

Currently there is no peatland management policy in the Boreal Forest of Alberta, but with increased industrial activities it became evident that peatlands need to be managed and protected. The purpose of the current study was twofold: 1) to develop an ecological peatland management key and in the process assess peatland resources using the Alberta Wetland Inventory (AWI) Standards and linear disturbances; and 2) to test if the AWI peatland landscape classification is congruent with on-ground floristic assessments, and if either scale can be used to identify peatlands that have rare plant species present. A peatland management key was developed for landscape scale assessments and on-ground ecological evaluation. Peatland resource assessment showed that peatland types can range from common (almost 30%) to rare (< 0.02%) and that only one peatland type was not affected by linear disturbance. Results for objective 2 indicated that AWI classification is not congruent with on-ground floristic groups, but that on-ground floristic groups may be used to identify rare species habitat.

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CHAPTER I: GENERAL INTRODUCTION

Alberta has an abundance of peat deposits that cover over 10.3 million ha of the province (Vitt et al., 1996), most of which are located in the northern half of the province or green area. Currently there is no policy for managing peatlands in the green area (Alberta Water Resources Commission, 1993), but with increased industrial activity it is evident that peatlands need to be protected and managed.

Industries that have an impact on boreal peatlands are conventional oil and gas, forestry, oil sands operations (open pit mining and in situ operations), agriculture, and horticultural peat companies. The single largest impact may be generated by disturbances caused by seismic lines, pipelines, and lease sites. Applications for 924,016 km of seismic lines were approved between 1979 and 1995, over 88,588 well sites existed by June 1997, and over 73,102.89 km of pipeline have been laid by December 1996 in the green area (Alberta Environmental Protection, 1998a).

Open pit mining in the Fort McMurray region exceeded 15,000 ha in 1997 (AEUB, 1997) but the presently disturbed area is much larger due to recent aggressive expansions and new developments. Other industries impacting peatlands are forestry, agriculture, and horticultural peat companies but to a much lesser extend.

Horticultural peat companies wanted a provincial peatland policy to identify sensitive areas and avoid costly environmental impact assessments when selecting potential bogs for harvesting. Out of this need, the Peat Management Task Force (PMTF), an association of the peat industry, the University of Alberta, and the provincial government was formed. Its mandate is "to provide information that will contribute to the orderly development and conservation of peatland ecosystems" (Peat Management Task Force, 1996).

To reach the objective, a *Peatland Summary Map* at 1:1,000,000 scale (Vitt, 1992) was produced. Peatland inventory and classification were based on the Alberta Wetland Inventory (AWI) Standards (Halsey & Vitt, 1996), a classification system for aerial photograph interpretation. AWI classification is based on landforms and vegetation

groups such as trees, shrubs or graminoids, but work by Vitt et. al. (1995), Belland and Vitt (1995), and Vitt and Chee (1990) showed that plant species distribution in peatlands is largely influenced by microhabitat diversity, especially moisture regime and shade. Microhabitat diversity can not be identified on aerial photographs because of the relative small scale used for mapping.

While it made sense to use the AWI to assess types and amounts of peatland resources in an large and often inaccessible landscape, the question of how to manage Alberta's peatlands, especially rare species habitats, still remained.

The purpose of the current study was twofold: 1) to develop an ecological peatland management key and in the process assess peatland resources using the Alberta Wetland Inventory (AWI) Standards and linear disturbances; and 2) to test if the AWI peatland landscape classification is congruent with on-ground floristic assessments, and if either scale can be used to identify peatlands that have rare plant species present.

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CHAPTER II: PEATLAND MANAGEMENT AND CONSERVATION IN BOREAL ALBERTA

INTRODUCTION

Background of Peat Management Task Force and Project

The Province of Alberta has an abundance of peat deposits in its Boreal Forest Region. Most bogs and fens are located in the green area and cover 16.3 % or 10.3 million ha of the province (Vitt et al., 1996). The green area, also referred to as the non-settled area of the province, generally covers the Boreal Forest Natural Region in the northern part of the province.

Horticultural peat companies in Canada prefer the weakly decomposed *Sphagnum* peat found in bogs and although in 1992 horticultural peat companies only extracted 0.02 % (approximately 16,000 ha) of all peatlands in Canada (Keys, 1992), *Sphagnum* peat extraction in Canada has been increasing steadily over the last 10 years (Joosten, 1995).

Currently there is no policy for managing peatlands (and other wetlands) in the non-settled area of the province (Alberta Water Resources Commission, 1993), but with the increase in peat extraction, it became apparent that resource management guidelines were needed. In Alberta, the peat industry took a proactive attitude and approached the University of Alberta to assess the provincial peatland resource and possible management tactics. Together, they approached the provincial government to become a partner in creating a policy for peatland conservation and development. Out of this need, the Peat Management Task Force (PMTF), an association of the peat industry, the University of Alberta, and the provincial government was formed. Its mandate was "to provide information that will contribute to the orderly development and conservation of peatland ecosystems" (Peat Management Task Force, 1996).

To reach the objective, a *Peatland Summary Map* at 1:1,000,000 (Vitt, 1992) and an inventory document *Peatland Inventory of Alberta* (Vitt et al., 1996) were produced. Based on the map and inventory, a region with a high concentration of peatlands was chosen to start Phase II of the PMTF's objective.

The objective of Phase II was to develop an ecological peatland ranking system for sustainable peatland ecosystem management in the green area of the Province of Alberta. The ranking system is the first formal provincial approach to peatland conservation and management from an ecological perspective.

Peatland Policy in Alberta

The purpose of this thesis was to develop a ranking system for peatland conservation and management and not to make policy; however, the lack of policy created a need for a model or basis by which to make decisions. Canada has *The Federal Policy on Wetland Conservation*, but this policy only covers approximately 29% of all wetlands, most of which are located in the northern territories, and others that are in national parks, community pastures, ports and harbour land, wildlife areas or crown holdings (Environment Canada, 1991). The objective of the federal policy is to "promote the conservation of Canada's wetlands to sustain their ecological and socio-economic functions, now and in the future" (Environment Canada, 1991). One major goal is "no net loss of wetland functions on all federal lands and waters" (Environment Canada, 1991). The Canadian Government respects, among others, the following guiding principles: "...wetland conservation is dependent on the incorporation of environmental objectives into socio-economic decision making;...Wetlands and wetland functions are inextricably linked to their surroundings...and therefore wetland conservation must be pursued in the context of an integrated systems approach to environmental conservation and sustainable development; ...Wetlands...are a desirable element of Canada's natural diversity; as such, they are priority requirement of environmental conservation and sustainable development efforts; ...Wetland conservation can only be achieved through a coordinated, cooperative approach involving all levels of government and the public, including landowners, non-government organizations, and the private sector" (Environment Canada, 1991).

The federal policy does have a strong emphasis on wetland and environmental conservation as the above excerpts show. It would be desirable if Alberta were to adopt

similar principles so that conservation efforts can be joint. The federal policy does not apply to land under provincial jurisdiction; therefore, the vast peatlands (and all other wetlands) stretching across the provinces are not protected by it.

Alberta has a wetland policy for the pothole region in the "southern, settled" or "white" area of the province, where development (farming, cattle ranching, and other human activities) subjected sloughs and marshes to tremendous pressures, drastically changing the typical prairie landscape. In 1993, the *Wetland Management in the Settled Area of Alberta - an interim policy* was released by the *Alberta Water Resource Commission*, and implementation became the responsibility of individual provincial government departments. Few peatlands exist within the white area and "policy intents for peatlands are not provided in this policy" (Alberta Water Resource Commission, 1993).

In northern Alberta, most land is public land. This area is referred to as the "green area" or "non-settled" area. No policy exists for wetland management in the green area but in 1993, *Beyond Prairie Potholes: A draft policy for managing Alberta's peatlands and non-settled area wetlands - for discussion purposes* was released by the *Alberta Water Resource Commission*. The non-settled area covers 53% of Alberta (Water Resource Commission, 1993) and most peatlands, 16.3 % of the entire province (Vitt *et al.*, 1996), are located within it. And although 7 years passed since the release of the draft policy, it was never ratified. Hence, currently there is no policy for provincial peatland conservation or management in Alberta. One should also note that the provincial draft policy does not endorse a "no net loss of wetland functions" principle as the federal policy does.

Impacts on Peatlands - non peat harvesting

Natural resource industries other than horticultural peat companies are operating in the Boreal Forest Region of the Province. Major industries are conventional oil and gas, forestry, oil sands operations (open pit mining and in situ operations), and agriculture. Activities associated with oil, gas, and mining industries affect peatlands and

uplands alike in the boreal forest. Lease sites, seismic lines, access roads, and pipelines dissect peatlands; thus, fragmenting habitats and affecting hydrology, flora, and fauna.

Mining operations, especially open pit mining in the Fort McMurray region, remove vast tracks of overburden and leave large ecological footprints. In 1997 an area of approximately 15,000 ha was mined (AEUB, 1997) but recent expansions (e.g. Aurora and Steepbank Mines) increased this surface area substantially.

The single largest impact may be generated by disturbances of seismic lines, pipelines, and lease sites. A 1998 Alberta Environmental Protection report states that between 1979 and 1995 applications for 924,016 km of seismic lines were approved for the green area. Based on the approved seismic line lengths and widths, it is estimated that roughly 4,971.11 km^2 (or > 53 townships) were cleared in the green area after 1979. A total of 88,588 well sites existed in the Boreal Forest Natural Region (BFNR) by June 1997, generating a well site density of 0.2553/km^2. A total length of 73,102.89 km of pipeline have been laid in the BFNR by December 1996 (Alberta Environmental Protection, 1998a). While the BFNR and the green area do not exactly cover the same area much of it overlaps; the BFNR area covers 346,964.37 km^2 and the green area covers 350,428.05 km^2 of the landscape.

The above figures clearly demonstrate that habitat fragmentation of peatlands and other ecosystems in the Boreal Forest is primarily caused by the hydrocarbon industry.

A further threat to peatlands, although not presently the norm, are peat-fueled power generating stations. Currently only one peat-fueled power generating station exists near Westlock. Fuel peat is obtained from landowners that drained peatlands to convert them into grazing land. The peatland trees are usually burnt and the peat is stockpiled into wind-rows for drying (pers. comm. Bryon Duddley, Westlock Algonquin Power). Because the objective is to convert peatlands into more valued grazing lands, the peat is a by-product and therefore relatively cheap. The cheap, dry, and easily available peat presented itself as good fuel source to generate electricity. Peat-fueled power generating stations are exceptions at present in Alberta and Canada, but fluctuating world oil prices and electricity demands will determine future use of large-scale peat-fueled power plants.

Other countries are well known to utilize peat as a fuel source for power generation at a large scale. Internationally, 30 million tonnes of fuel peat are extracted annually for the production of electricity and hot water, and Sweden, Finland, and Ireland are still using peat for energy production (Joosten, 1995), but the major consumer of fuel peat is Russia with 7.6 million tonnes in 1992 (Savelyev, 1994). If peat should become a general source for power generation in Alberta, the rate of peat extraction would drastically increase.

Drainage of peatlands for forestry purposes is currently only practiced on an experimental basis in Alberta. Trees in peatlands usually exhibit stunted growth and are not profitable for timber harvest. Wood production can be increased by lowering water levels at the cost of peatland loss. Experimental draining in Alberta started in 1981 under the *Wetland Drainage and Improvement Program,* a program initiated under the *Canada-Alberta Forest Resources Development Agreement* (Hillman et al., 1997).

Under this program, 4 million hectares of Alberta's peatlands were considered suitable for draining; however, present pulpwood prices make such a venture unprofitable (Hillman et al., 1997). Hillman et al. (1997) stated that "none of the [considered] areas reveal very high site values after drainage" and that "tree growth on organic soil in Alberta is difficult or impossible to predict due to the lack of documented tree growth data for such areas in the province". It should be noted that fluctuating pulp wood prices, and distance to available pulpwood sites, may make such a venture feasible in the future, especially since similar European programs showed promising results with an increase in wood volume of up to $300m^2\ ha^{-1}$ (Hillman et al., 1997).

Ecological Description Boreal Peatlands in Alberta and Literature Review

In order to better understand why certain criteria and algorithms were chosen, a brief literature overview of the ecology of peatlands in the Boreal Forest is given below.

Continental boreal peatlands originated between 9,000 ^{14}C and 3,000 ^{14}C years BP (Halsey et al., 1998; Zoltai et al., 1988). They generally exist where annual precipitation is > 500mm, biotemperature is < 8°C, and evapotranspiration/precipitation ratios are < 1 (Gignac & Vitt 1994;). Peat is accumulated because production exceeds decomposition

due to anaerobic conditions and low temperatures. Peat depth in Alberta peatlands varies but can reach over 6 m (pers. observations).

Decomposition of plant matter, and thus peat accumulation, is very slow and not constant over time (Gorham, 1991). Decay may continue anaerobically over 100s to 1000s of years (Clymo, 1984), and rates of long term peat accumulation can best be measured by radio carbon dating (Gorham, 1991). Gorham (1991) calculated a peat accumulation rate (in height) of 0.5mm/year from 138 basal ^{14}C dates for Canadian peatlands (subarctic and boreal region). This rate is similar to the average rate of 6.4 cm/100 years calculated for 35 boreal peatlands by the National Wetlands Working Group (1988). Variations in peat accumulation can be attributed to floristic composition, degree of decomposition, and compacting of peat (National Wetlands Working Group, 1988).

Continental boreal peatlands include geogenous fens and ombrogenous bogs. Fens receive mineral enriched groundwater while bogs are raised above the water level and receive water from precipitation only. Important factors in peatland development and classification are hydrology, chemistry, and biotic factors. A combination of these factors results in the development of a ground layer dominated by *Sphagnum* or brown moss (Zoltai & Vitt, 1995). Conductivity and alkalinity are highly correlated indicating that vegetation distribution along the bog to fen gradient is related to surface water acidity-alkalinity (Vitt & Chee, 1990). Rich fens are associated with alkaline waters often rich in calcium and bicarbonate while bogs and poor fens are associated with acid waters and little or no alkalinity (Vitt & Chee, 1990).

Alberta's fens can be divided into poor, moderate-rich, and extreme-rich fens based on their surface water pH, cations, conductivity and associated vegetation (Chee & Vitt, 1989; Vitt & Chee, 1990; Vitt et al., 1995). They can be dominated by sedges, grasses, shrubs or *Sphagnum* representing a chemical and moisture gradient (Vitt & Chee, 1990). Only two tree species are normally associated with Alberta's peatlands: *Larix laricina* (Du Roi) K. Koch and *Picea mariana* (Mill.) BSP; the latter is the only tree species in bogs.

Generally, bogs are acidic (pH < 4) and dominated by oligotrophic *Sphagnum* species (Vitt, 1994). Poor fens (pH 4.0-5.5) are dominated by oligotrophic *Sphagnum* species while moderate-rich fens (pH 5.5-7.0) and extreme-rich fens (pH >7.0) are characterized by brown mosses (Vitt, 1994). Moderate-rich fens can also have mesotrophic species of *Sphagnum* such as *S. subsecundum* Sturm, *S. warnstorffii* Russ. or *S. teres* (Schimp.) C. Hartm. (Vitt, 1994).

Few fens are found within the pH range of 5.1-5.6 (Vitt, 1994). In this range alkalinity drops to zero and the peatland becomes *Sphagnum*-dominated (Vitt, 1994). This transition is rapid (100-200 years) because *Sphagnum* can acidify its environment, thus causing oligotrophication (Kuhry et al., 1993; Vitt et al., 1994).

South of the continuous permafrost zone, peatlands can be underlain by permafrost. The southern limits of discontinuous permafrost is at the 0°C to - 1.1°C isotherm (Brown, 1967). Permafrost-dominated peatlands (including peat plateaus) are raised above the water table and drier conditions allow for dense, tall conifer growth in the south, and open-canopy, *Cladina*-dominated plateaus in the north (Vitt et al., 1994). Most permafrost in the discontinuous permafrost zone of Alberta is restricted to ombrotrophic peatlands.

Permafrost-underlain peatlands can be subject to thawing and two landform features are common in continental western Canada: collapse scars and internal lawns (Zoltai, 1971; Vitt et al., 1994). Collapse scars are typically up to 1 m lower than the surrounding permafrost underlain peat surface. The wet area of the collapse is often dominated by *S. riparium* but *S. angustifolium* is present as well Zoltai (1993). It is important to note that collapse scars form treeless circles (leaning trees at the margins are common) within the matrix of permafrost underlain peatlands.

Internal lawns are generally dominated by "wet" species of *Sphagnum* and *Carex* (Vitt et al., 1994) but later successional stages may be dominated by ombrotrophic *Sphagnum* and *Eriophorum* (pers. observation). Partially buried, leaning trees, dead or alive, are often present (Vitt et al., 1994). Internal lawns are remnants of permafrost collapse, but they are not surrounded by permafrost.

Peatlands in continental Canada developed post-glacially during the Holocene and initially were free of permafrost for thousand of years, indicating that the climate was warmer than the present (Zoltai, 1995). Since peatland development and permafrost initiation is largely governed by climate, development and initiation generally occurs earlier in the north than in the south. The earliest permafrost collapse surface in Alberta was dated approximately 3,700 years ago at the NW corner of the province, probably indicating a minimum date for the onset of permafrost development at this latitude and elevation (Zama Lake, 59°09'N, 118°42'W; 340-600m a.s.l.) (Zoltai, 1993). At the southern limits of discontinuous permafrost, present permafrost distributions may be relicts of the Little Ice Age (A.D. 1550-1850), and are therefore much younger. Radiocarbon dates from the surface of subsided silvic peat in collapse scars are less than 200 years old (Vitt et al., 1994). Dendrochronological data of initiation of leaning live trees show that subsidence began approximately 150 years ago and continues to the present (Vitt et al., 1994), suggesting that permafrost melting in the south was initiated at the end of the Little Ice Age.

Peatcores taken from internal lawns in Alberta showed typical sequences from top to bottom as follows: a wet, oligotrophic species of *Sphagnum* associated with later stages of collapse; a thin layer of sedges associated with wetter but nutrient poor conditions; a thin layer of *Polytrichum strictum* or *Pleurozium schreberi* and wood and/or black spruce needles associated with permafrost mounds; and finally a thick layer of decomposed macrofossils associated with dry wooded bog (Vitt et al., 1994).

Such evidence of permafrost decline and subsequent successional stages can be used in monitoring global climate change, reconstructing past climates and peatland development, and in predicting biodiversity.

Criteria Chosen for Peatland Management and Conservation

The objective was to develop an ecological system for applied landscape management for boreal peatlands. Many excellent papers have been written on reserve selection and conservation (Pressey et al., 1996; Underhill, 1994; Nicholls & Margules

1993; Pressey et al., 1993; Bedward et al., 1992; Vane-Wright et al., 1991; Margules et al., 1988; Smith & Theberge, 1986;) but few address natural resource management on the landscape level, and even fewer address natural resource management of peatlands (bogs and fens) within the Boreal Forest.

Criteria that can be used in boreal landscape management need to be easily applied to Geographic Information Systems (GIS) data bases, give a measure of ecological importance, highlight conservation issues, identify problem issues, portrait a clear picture, be subjectable to a clear algorithm, and allow for usefulness in decision making in natural resource management. Criteria chosen can be limited by the resources available (time and finances) and the project goal.

The use of spatial analyses tools such as GIS are necessary when managing natural resources on the landscape level. Although Phase II study area represents only a portion of Alberta's Boreal Forest, it covers 12,556 km^2 or 1,255,600 ha. In order to analyze peatland resources a GIS data base was generated using the Alberta Wetland Inventory Standards (AWI) (see mapping and inventory). The data base was used to calculate relative peatland type abundance within Phase II study area (see methods), presence of permafrost features (contained in the AWI classification), and peatland type rarity.

A GIS data base can be used in many ways in resource management. For example, Alberta is classified into six natural regions, 20 sub-regions (Achuff, 1994), and 282 ecodistricts (Strong & Thompson, 1995) based on a combination of biophysical attributes. It would be an obvious choice to use ecodistrict boundaries for ecological management but Phase II study area was chosen by the PMTF by township boundaries. Township boundaries have square dimensions and form a grid whereas ecodistrict boundaries are based on biophysical attributes. Once the entire province, or at least the Boreal Forest Region, is mapped and inventoried, ecodistrict boundaries can be used in peatland management. Phase II area touches on ecodistricts No. 47, 52, and 61, and because Phase II study area is delineated by the townships, small areas (1/2 - 1/4 townships) extent into ecodistricts No. 71, 72, 38, 62, and 64.

Linear disturbance data were readily available in a suitable GIS format from the

provincial government that had just commissioned a report on the Boreal Forest Natural Region. The linear disturbance layer was used to overlay the peatland layer and not only calculate disturbance length, area, and edge effect but also to identify peatlands that were not impacted by anthropogenic disturbances.

Except for linear disturbance data from the provincial government, no other data were used in this study for the following reasons, in addition to the limitation of time and financial resources: lack of availability of data sets (data may not be available because the originator is still working with them), proprietary issues (who paid for the work, and hence, whose data is it?), shape of data set (e.g. file format if at all available in digital format), and amount of secondary analyses required (e.g. species telemetry data).

All on-ground data used for the ranking system were generated through sampling within Phase II (see methods). Limitations of criteria chosen are briefly discussed below. Ideally, all organisms are sampled in a study for ecological ranking but most experts in the field would agree that this would be an enormous task and also would not answer all questions.

Sampling fauna poses several problems some of which are the mobility of the organism and the seasonality of the species, especially true for life cycles of invertebrates or breeding and migrating birds. Lack of access and difficulties in transversing peatlands often necessitates the use of helicopters. Noise disturbance makes it impossible to inventory such groups as birds - either nesting or migrating. Small mammals need to be trapped to take a census. Here again, accessibility become an issue, especially when trying to sample individual peatlands that cover over 12,000 km^2 and have next to no road access. It should be noted that setting up base camp in the muskeg is rather challenging and time and energy consuming. Similarly, to take a census of invertebrates, reptiles, and amphibians would pose the same problems.

The below given criteria (Table 2.1) were used in the ecological ranking system. Other criteria could have been incorporated into the system if resources were unlimited. Criteria that may be added as the system matures. Research needs and possible criteria are suggested in the recommendations.

Table 2.1. Criteria used in the ecological ranking system.

Criteria:	Data Source:
1. Relative peatland type abundance within Phase II study area	GIS data base from AWI inventory and mapping - Phase II
2. Species diversity and abundance	based on plant species diversity, vascular plants, bryophytes and lichens - Phase II
3. Rare, threatenend, or endangered species	based on ANHIC and Alberta Fish and Wildlife, Alberta Environment
4. Anthropogenic disturbances	based on Alberta Environment data for linear disturbance
5. Research history	based on Phase II study
6. Future research	undisturbed sites as identified in the above data, research history as identified from this study, presence of rare species from this study and Alberta Environment

Relative peatland type abundance within Phase II study area

Aerial photograph interpretation and the Alberta Wetland Classification (AWI) (Halsey & Vitt, 1996) were used to inventory the study area. While some aspects of peatland ecology such as bryophyte diversity or water chemistry cannot be assessed using remote sensing, it should be recognized that remote sensing and GIS applications are extremely useful tools in landscape ecology and management. It would be irresponsible not to use these tools for large ecosystems like the Boreal Forest.

The GIS data base allowed for calculation and analysis of peatland type abundance by peatland type or surface area and the linking of individual polygons with information such as geographic locations.

The classification used in this inventory is the AWI that allows for the differentiation of bogs and fens based on hydrology, tree cover (forested >70% trees, treed 6-70% trees, and open < 6% trees), complex landforms (patterning, permafrost presence), local landforms (collapse scars, internal lawns, permafrost islands), and if < 6% tree cover, of shrub or graminoid cover.

The AWI is meant to be a classification that is applicable to the landscape scale for resource management, but its limitation must be recognized when making peatland management decisions. Water chemistry and associated vegetation and moisture regime cannot be assessed from aerial photographs but are extremely important and can be dealt with via ground surveys in peatlands in question.

Species diversity and abundance

The goal is to conserve species diversity and ecological integrity. Peatlands ranging from bogs to extreme rich fens represent a spectrum of environmental conditions and therefore a spectrum of species diversity and abundance. Species diversity in this project is based on plant diversity - vascular plants, bryophytes, and lichens. Plants range over a wide environmental gradient and create many habitats for other organisms. By conserving these environmental gradients, habitat, food and shelter for other organisms are protected.

Environmental gradients as well as permafrost features create a variety of unique meso and microhabitats for bryophytes (Vitt et al., 1995) and vascular plants. Meso and microhabitats are for example collapse scars (where permafrost melted), permafrost mounds, hummocks, hollows, or pools. The higher the peatland heterogeneity, the greater bryophyte species diversity is expected (Vitt et al., 1995).

While vascular plant species respond more to differences in concentrations of nutrients and bryophytes to differences in acidity (Vitt and Chee, 1990), habitat heterogeneity may still influence species diversity of both groups.

This may also be true for other organisms, especially invertebrates. In general, when total diversity is considered bogs and poor fens are less diverse than many rich fens; however, at the site level, bogs may be just as species rich as fens.

Little is known about the ecological niche of invertebrates in peatlands but a few recent studies suggested high invertebrate abundance and diversity. For example, sampling a spring fen near Edmonton, Alberta for terrestrial arthropods yielded 2,181 species, bringing the total of known species in peatlands to 2,905 (Finnamore, 1994). To my knowledge no detailed diversity study focusing on birds or small mammals has ever been carried out in the vast peatland complexes of Alberta, especially studies that link animal species to peatland types under the AWI.

Utilization of peatland types by endangered, threatened, or rare organisms

Habitat loss is the largest threat to endangered, threatened, or rare species. In Alberta, the rare slender-leaved sundew (*Drosera linearis*) and the threatened woodland caribou (*Rangifer tarandus caribou*) are examples of organisms depending on peatlands. Although detailed research has been carried out in Alberta's peatlands, the focus has been mainly on vegetation, water chemistry, and permafrost (Vitt, 1994; Zoltai et al., 1988; Halsey at al., 1998; Vitt & Chee, 1990; Chee & Vitt, 1989; Zoltai & Vitt, 1995; Kuhry et al., 1993; Vitt et al., 1994; Zoltai, 1971; Zoltai, 1993, Gignac & Vitt, 1994; Vitt & Belland, 1997; Vitt et al., 1995; and Belland & Vitt, 1995). Data for invertebrates became available through *The Biological Survey of Canada* but its shortcomings are the

inconsistency in wetlands terminology used (Rosenberg & Danks, 1987). Because of misused terminology, it is not clear which groups or species are obligates to certain peatland types.

Presently the best provincial source for tracking endangered, threatened, or rare organisms is the Alberta Natural Heritage Information Centre (ANHIC) and the Alberta Wildlife Management Division, Alberta Environment. ANHIC tracks vascular plants, mosses, and lichens (the latter list is in progress) whereas Alberta Wildlife tracks vertebrates. Other sources for evaluating floral and faunal rarity may be herbaria and the Provincial Museum, respectively. Agriculture Canada, in addition to the Provincial Museum, may also provide invertebrate species data. While excellent collections often exist, it is often tedious and labour extensive or next to impossible to compile available data into shape for analysis.

Anthropogenic disturbance in Alberta peatlands

Fire and logging are excluded from anthropogenic disturbance in this study. The Boreal Forest evolved with wildfires, and although some fires are human caused, fire is part of the boreal ecology. Presently there is no logging on peatlands in Alberta due to the low yield and the difficulty of operating machinery on soft ground.

Disturbances in peatlands that should be evaluated are peat harvesting, seismic lines, well sites, pipelines and roads. Many of these features are mapped and the degree of disturbance can be evaluated by spatial analysis.

Linear disturbance is of concern in Alberta's Boreal Forest due to high hydrocarbon industrial activity as demonstrated by Alberta Environmental Protection (1998a). Linear disturbance, mainly seismic lines, causes habitat fragmentation to the degree of creating habitat islands and the associated issues of species migration, isolation, and edge effect (Alberta Environmental Protection, 1998a). Peatland disturbance can change the hydrology thus possibly changing water chemistry, moisture levels, and vegetation. Human activities can also interfere with wildlife behaviour and make an area less desirable for some organisms such as caribou.

Research History

Peatlands in which research has been carried out should be conserved for future reference. This will ensure that peatland data (all aspects - flora, fauna, chemistry, carbon, permafrost, and possible other) are not lost and long time monitoring is possible. Long time monitoring is important for studying such issues as climate change and peatland development and function. In order to preserve such data, a central "clearing house" is needed. Possible locations would be the Stephen C. Zoltai Peatland Resource Centre or the Prairie & Northern Plant Diversity Centre, both at the Devonian Botanic Garden, University of Alberta.

Future research

The following peatlands should be considered as future research sites: undisturbed peatlands, peatlands with permafrost present, peatlands that provide habitat to rare species, and peatlands that have a research history. Peatlands that have not been disturbed provide the opportunity to study paleobotany, peatland development, and paleoclimate patterns. Such peatlands may become benchmarks for future conservation decisions.

Permafrost presence and decline may provide vital information to climate change and ecological responds to it. Present day permafrost behaviour and peatland stratigraphy may allow for modeling of future trends and predictions of climate change impacts on the Boreal Forest.

Peatlands that provide habitats to rare species are more than likely different from other peatlands in that they have some attributes that provide rare species habitat. Environmental change may be monitored by rare species presence or abundance, or any change over time of the rare species. In other words, rare species may be monitors of environmental health and/or stability.

Peatlands that have a research history should be earmarked for monitoring change, especially in relation to the above points. Research history means that data have been collected in the given peatland for one to several variables, and these data can be used for

comparison studies. To monitor change of peatlands may be very important not only in light of climate change but also in light of increasing industrial activity in the Boreal Forest.

Algorithm

Most evaluating systems use a multi-criteria approach and an algorithm that focuses on minimum site selection to conserve representative sites and biodiversity (Smith & Theberge, 1986; Nicholls & Margules, 1993; Pressey et al., 1993; Underhill, 1994; Pressey et al., 1996). A constraint is sometimes added to ensure that each ecosystem type is represented and not only species rich sites (Margules et al., 1988). The idea is that if all ecosystem types are represented they will serve as a "coarse filter" and will capture the biodiversity of the landscape. Organizations such as The Nature Conservatory (TNC) use a similar approach: " TNC's coarse filter is expected to preserve perhaps 85-90% of the species complement of a state, without having to concentrate on each species individually" (Nature Conservancy, 1981-1984 in Noss, 1987). "Species that 'fall through' the coarse filter - generally those that only occur in only a few examples of recognized community-types - are captured by the 'fine-filter' of threatened and endangered species classification" (Noss, 1987). Hence, adding a constrain to represent all ecosystem types would be very important in peatland landscape scale management because not all peatlands can be sampled.

The following is only an example of an algorithm that may be used here. Analysis of ecological peatland communities, peatland maps, caribou peatland habitat, species diversity, and disturbance will determine details of the algorithm and constrain.

An example of an algorithm may be:

1) select rare peatland types (e.g. a given number of polygons within a region or management unit) that should be set aside for conservation
2) select peatlands with high species diversity (high number of species)

3) select at least x number of (an appropriate number) representative peatlands in each management unit

4) select all peatlands with no anthropogenic disturbance

5) select all peatlands that we know are used by caribou

6) and possible others...

METHODS

Study Area and Site Locations for Phase II

A study area of 12,556 km^2 (Fig. 2.1) was chosen based on peatland density based on the Alberta peatland inventory summary map at 1:1,000,000 scale (Vitt, 1992). The map indicated a high concentration of peatlands within northeastern and northcentral Alberta's Aspen Parkland and Boreal Forest. Sample locations (sites) were chosen with the objective to obtain representative samples from within the entire study area. An effort was made to obtain multiple inventories for each peatland type as identified under the Alberta Wetland Inventory Standards (Halsey & Vitt, 1996). 135 plots were sampled between June and the end of August, 1996. Each site had at least 40 cm of peat but in most cases the peat depth was greater. The benchmark of 40 cm of peat was chosen because the Canadian Wetland Classification System (National Wetlands Working Group, 1988) bases peatland classification on a peat depth of 40 cm or more. The study area represents approximately 3.6% of the green area. The geographical limits of the study area are 56°01′ (most northern limit) and 54°51′ (most southern limits) latitude, and 111°04′ (most eastern limit) and 113°52′ (most western limit) longitude. Sample locations are identified in Fig. 2.1 and in the digital data base.

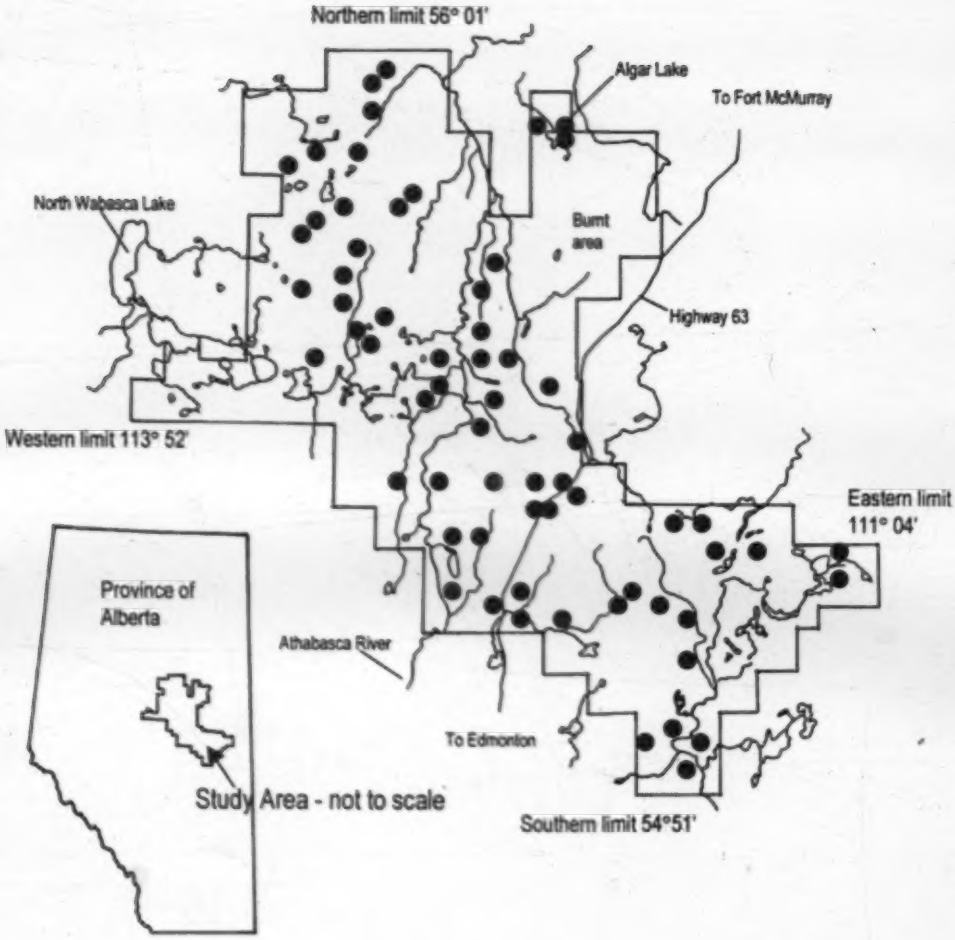

Fig. 2.1. Study area (12,556 km²) in northeastern Alberta, Canada. Dots represent study locations; one dot may represent more than one site.

Mapping and Inventory

Peatland Classification - Alberta Wetland Inventory Standards

Alberta Wetland Inventory (AWI) Standards (Halsey & Vitt, 1996) were used to classify and inventory peatlands within the study area. Under these standards, peatlands are classified by four-letter codes that identify the following four categories: wetland class, vegetation modifier, wetland complex landform modifier, and local landform modifier (Table 2.2). Two peatland classes exist, bogs and fens. An overview of peatland types is given in table 2.2 and ecological descriptions of peatlands and permafrost features (wetland complex modifiers and local landform modifiers) are given in the introduction under the subheading *Ecological Description of Boreal Peatlands in Alberta and Literature Review* (p. 8).

Polygon size limitations & decision rule for mixed vegetation/local landform modifiers

Only peatlands larger than 0.5 ha were mapped because of the size limitation at the 1:50,000 scale. A 0.5 ha square is represented by 0.141 x 0.141 cm or 0.02 cm^2 on the map or by 70.71 x 70.71 m on ground. If polygons smaller than 0.5 ha were adjacent to a larger peatland polygon, then they became part of the larger polygon.

Aerial photograph interpretation is not an exact science as the term "interpretation" suggests. As always in aerial photograph interpretation, decisions on how to classify a polygon are made on individual polygon basis and interpreters may not always agree on how a polygon should be classified. This does not indicate lack of professionalism or shortcomings in a classification system, but simple the diversity and gradients of the natural landscape. However, AWI Standards were followed as closely as possible and in cases where polygons of 0.5 ha had two different vegetation modifiers and/or local landform modifiers (e.g. shrubby but grading into graminoid; or treed but grading into shrubby), the vegetation/local landform modifier that covered over 50% of the polygon was chosen for the classification. In borderline cases, the interpreter made

Table 2.2. AWI Standards peatland classes used in inventory and classification (table modified from Halsey & Vitt, 1996). A letter from each category is used to classify peatlands to AWI Standards. Examples might be BTNI (bog, treed, no permafrost or patterning, internal lawn) or FONS (fen, open, no patterning or permafrost, shrub dominated).

Landscape Features	Description of Landscape Feature		Letter Code
Wetland Class	bog		B
	fen		F
Vegetation Modifier	forested:	tree canopy closure > 70%	F
	treed (wooded):	canopy closure > 6% but < 70%	T
	open:	tree canopy closure < 6%	O
Wetland Complex Landform Modifier	permafrost present		X
	patterning present		P
	neither permafrost nor patterning present		N
Local Landform Modifier	collapse scar(s)		C
	internal lawn(s) with island(s) of forested peat plateau		R
	internal lawn(s)		I
	none of the above local landform modifiers present		N
	if tree canopy closure was < 6%, then identify graminoid or shrub dominated:		
		shrub cover >25%	S
		graminoid cover > 25%	G

the best possibly judgement call.

Source photography and scale used

Phase II study area is partially located within the Forest Management Agreement (FMA) of Alberta-Pacific Forest Industries Inc. (Al-Pac) in northeastern Alberta. As Al-pac was completing the Alberta Vegetation Inventory (AVI) of its FMA, Phase II was mapped as well. Under the AVI, wetlands were not inventoried but were mapped as *non-forested vegetated land* categories.

As Phase II was begun, it was decided by the Peat Management Task Force that all wetlands should be mapped and replace all *non-forested vegetated land* polygons with AWI classes. Only a part of Al-Pac's FMA was mapped at the time, but the company agreed to make orthophotos (1:15,000) and the digital data base available to generate a wetlands inventory. Table 2.3 lists the 84 out of 132 townships that were inventoried using orthophotos. New wetland polygons were generated in the above data base by selecting relevant AVI polygon numbers and re-classifying the *non-forested vegetated land* polygons in the digital data base. This data base became the new wetlands coverage.

Panchromatic aerial photographs at 1:40,000 scale were used in addition to the orthophotos in cases where stereoscopic coverage was necessary to classify a polygon. In areas where polygons had to be split, the missing lines were digitized and the newly generated polygons were labeled accordingly. Where adjacent polygons received the same identifier, one new polygon was generated.

The remaining area was inventoried and mapped using panchromatic aerial photographs only. The latest available photographs for the area were at the 1:40,000 scale and were flown between August 1990 and October 1993.

One seamless wetland layer (AWI inventory) was generated from the direct aerial photograph interpretation and from the indirect orthophoto re-interpretation approach. Because of the two different scales, polygon edge fineness does differ; however, AWI classification does not.

Table 2.3. Orthophotographs (townships/ranges) and AVI used within Phase II study area for AWI. All townships are west of the fourth meridian. Townships are identified by a township and a range number, e.g. 83-18.

township	ranges
83	18,17
82	16, 17, 18, 22
81	14, 16, 17, 18, 22
80	15, 16, 17, 18, 22,
79	15, 16, 17, 18, 22, 23
78	15, 16, 17, 18, 21, 22, 23, 24
77	15, 16, 17, 18, 20
76	14, 15, 16, 17, 18, 20
75	10, 11, 12, 13, 14, 15, 16, 17, 18, 19
74	8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18
73	8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18
72	10, 11, 12, 13
71	11, 12, 13
70	12, 13
69	12, 13

Peatland Coverage Transfer

After all peatlands within the study area were inventoried and classified, mylar basemaps at 1:40,000 were obtained from Alberta Environment, Resource Data Division, Edmonton, Alberta. The basemaps contained, in addition to townships/ranges and latitude/longitude markers, water bodies, roads, cutlines, well sites, and pipelines based on aerial photographs from the 1970s; hence, not all present anthropogenic features were shown on the basemaps.

Peatland polygons were manually transferred onto the mylar basemaps by placing aerial photographs under the mylars and tracing peatland polygons. Placement of peatland polygons was controlled by features identified on the basemaps such as lakes, streams, ponds, cutlines, or lease sites. Hence, mapping accuracy may vary slightly with accuracy of polygon placement.

Where orthophotographs were used, AVI coverage was printed on mylar. The mylar copy was directly placed on the orthophotographs and the peatland polygons were identified and labeled on the mylar. Aerial photograph interpretation was used to confirm peatland classes on orthophotographs.

Where peatlands bordered existing polygons (e.g. lakes, marshes, AVI polygons), the existing border was used and only new lines were drawn when necessary.

Mapped polygon boundaries were transferred onto mylar base maps of the same scale and digitized in *GRASS*. The data base was imported into *Arc/Info* to edit, to finalize the inventory, and to analyze the data base for peatland resources.

Edge Matching

Orthophotos that were obtained from Alberta-Pacific Forest Products Ltd. were at the 1:15,000 scale and each orthophotograph represented one township. Digital AVI coverage of these townships was already edge-matched and AWI coverage was edge-matched by hand with printed copies of AWI polygons. If new peatland polygons were created from existing AVI polygons (i.e. non-merchantable timber polygons), existing lines were utilized where possible and new ones were edge-matched by hand as above.

Aerial photographs used for the remaining townships were at 1:40,000 scale. For the purpose of edge-matching, bordering orthophoto coverage was printed out at 1:40,000 for edge-matching by hand. Once edge-matched, AWI polygon labels were entered by hand in the digital data base.

The digital copy was checked for possible polygon errors, dangling lines, and erroneous or double labels. After completion of this step, the entire peatland coverage was printed at the 1:40,000 scale and checked against working copies of basemaps.

The digital data base of the AWI inventory was forwarded to Alberta Data and Resource Division, Alberta Environment, to print a series of 1:50,000 scale wetland inventory maps (Forest et al., 2000).

At the time the peatland layer was finalized at the Spatial Information Systems Lab, Department of Renewable Resources, University of Alberta, Edmonton, Alberta. Each wetland polygon within the study area has a unique identification number assigned by the sheer virtue of a GIS data base. Although the entire study area was inventoried for all wetlands, only peatlands are discussed in this thesis.

Relative peatland type abundance within Phase II study area

Relative peatland type abundance was calculated based on the AWI data base within the study area. To calculate the percent of relative abundance by surface area, a peatland type's area was divided by the total peatland area and then multiplied by 100 (e.g. for BTXN: ($0.96\ km^2$ / $4967.34\ km^2$) * 100 = 0.019 % of total peatland area). To calculate the percent of relative abundance by AWI peatland type polygon, an AWI peatland type's number of polygons were dividing by the total number of AWI peatland polygons and then multiplying by 100 (e.g. for BTXN: (3 / 6119) * 100 = 0.049% of total peatland polygons). Abundance was assessed by surface area and by the number of polygons within each peatland type.

Plant Inventory

A spatially unbounded-plot approach was taken to inventory vegetation. An

unbounded plot eliminated the need of finding a truly representative spot of a given size, typically a 5 x 5m or 10 x 10 m quadrat for vegetation inventory. It allowed for expansion of the area inventoried until no more new species were found.

Abundance was recorded in the following way: 3 = species is abundant throughout (dominant); 2 = species occur scattered throughout or in clusters e.g. confined to hummocks; 1 = species occur only scattered and infrequent; "+" = species only occur as a trace (adapted from Vitt et al., 1990). All vascular plant species, bryophytes, and lichens were recorded, except epiphytes.

Species nomenclature follows Moss (1994) for vascular plants, except for *Vaccinium oxycoccos* that follows Soper and Heimburger (1990); Crum (1984) for *Sphagnum;* Schuster (1966) for hepatics; Egan (1987) for lichens other than for *Peltigera;* Goffinet and Hastings (1994) for *Peltigera;* and Anderson et al. (1990) for Bryidae with the following exceptions: nomenclature follows Koponen (1974) for Mniaceae, Shaw (1982) for *Pohlia*, and Janssens (1983) for *Drepanocladus*. Throughout the text genus and species are given in most cases rather than using the convention of abbreviating the genus name after it appeared once.

Assessment of plant rarity and diversity on the landscape level

Plant species rarity was assessed by comparing the plant species inventoried to Gould (1999), the Alberta Natural Heritage Information tracking list. Gould followed the system developed by the Nature Conservancy for species tracking and rating. Specific site rarity from plant inventory data is discussed in Chapter 3, Forest (2000).

Anthropogenic disturbance

A linear disturbance data base that included well site data was obtained from Alberta Environmental Protection in 1998. The data base was generated by using 1989-1995 coverage and therefore do not represent the current disturbance regime but less (for detailed methods see Saywer and Haskins, 1997). The linear data base was laid over the peatland data base and disturbances in peatland polygons were analyzed in ArcInfo.

RESULTS

Relative Peatland Type Abundance within Phase II Study Area

GIS analyses of the peatland layer showed the following results. Within the study area of 12,556 km^2, 4, 967 km^2 (39.56%) are peatlands, 680 km^2 (5.34%) are other wetlands (swamps, marshes, or shallow open water), and 6,906 km^2 (55.02%) are mineral soil. A total of 6,119 peatland polygons larger than 0.5 ha were inventoried; smaller polygons were not identified because of mapping limitations at the 1:50,000 scale. If polygons smaller than 0.5 ha were adjacent to a larger peatland polygon, then it became part of the larger peatland. Only polygons larger than 0.5 ha are included in the total peatland surface calculations. Fifteen different peatland types were mapped according to Alberta Wetlands Inventory (AWI) Standards (Halsey & Vitt, 1996). Table 2.4 shows the number of polygons, by peatland type, percent of total peatland area, the size ranking by area, percent of total peatland polygons, and the polygon abundance ranking in ascending order.

Within the study area, the most common peatland types are treed fens (FTNN) and bogs (BTNN) (Table 2.4). Treed fens (FTNN) (1415 polygons) cover a total of 1473.11 km^2 and represent 29.656 % of the total peatland area and 23.125 % of the total peatland polygons, while treed bogs (BTNN) (2247 polygons) cover a total of 1362.06 km^2 and represent 27.420 % of the total peatland area and 36.722 % of the total peatland polygons. BTNNs are the most common type by the number of polygons and FTNN by surface area. Peatland type FOPI (open, patterned fens with internal lawns) is the least common peatland type by number of polygons (2 polygons) but covers a total of 2.87 km^2 and represent 0.058 % of the total peatland area and 0.033 % of the total peatland polygons. Peatland type BTXN (wooded permafrost bogs without collapse scars) was only mapped 3 times and covers a total of 0.96 km^2 and represent 0.019 % of the total peatland area and 0.049 % of the total peatland polygons. The distribution of the remaining peatland types is shown in Table 2.4.

Table 2.4. Summary of the 15 AWI peatland types inventoried: number of polygons per peatland type and area (in ha and in km2) and respective percentages.

peatland type	total polygons	area in ha	area in km2	% of total area	% of total polygons
BTXN	3	96.18	0.96	0.019	0.049
BFXN	11	137.55	1.38	0.028	0.180
FOPI	2	287.12	2.87	0.058	0.033
BTXC	36	747.57	7.48	0.150	0.588
BFXC	53	1022.80	10.23	0.206	0.866
FOPN	56	1848.44	18.48	0.372	0.915
FONG	178	2343.58	23.44	0.472	2.909
FTPN	47	2929.31	29.29	0.590	0.768
FTNR	120	16651.41	166.51	3.352	1.961
BTNR	189	26069.99	260.70	5.248	3.089
FONS	1198	43689.12	436.89	8.795	19.578
FTNI	245	46251.60	462.52	9.311	4.004
BTNI	319	71142.23	711.42	14.322	5.213
BTNN	2247	136206.31	1362.06	27.420	36.722
FTNN	1415	147310.51	1473.11	29.656	23.125
Totals:	6119	496733.73	4967.34	100*	100

* 100 percent of peatlands inventoried; peatlands smaller than 0.5 ha are not included in the above, regardless of area or number of polygons.

Plant Species diversity (number of species)

A total of 263 species, composed of 141 vascular plant species, 82 moss species, 28 hepatic species, and 12 lichen species (*Cladonia* species were only identified to genus) were identified in the sampled peatlands. Not all AWI peatland types were sampled because Phase II area was inventoried and mapped after field sampling. Hence, ground data only exist for 10 peatland types out of 15 types mapped, and only 9 peatland types were used for species diversity analysis because peatland type FTNR was only sampled once and is therefore not included. Based on plant species data, Analysis of Variance showed that all 9 peatland types differed between the types ($P < 0.05$) (Table 2.5). Mean plant species diversity and standard deviation are shown in Figure 2.2. Peatland type FOPN has the highest mean species diversity of 36.6 species and the highest standard deviation of 13.39 species, while peatland type FONG has the lowest mean species diversity and a standard deviation of 7.07 species and peatland type BTNN has a mean species diversity of 21.2 species but a standard deviation of 3.58 (Fig. 2.2). The narrowest range of the number of species was in peatland type FTPN (from 24 to 25 species, n = 3) while the widest range of the number of species was found in peatland type FTNN (from 12 to 53 species, n = 25) (Fig. 2.2). The most species per site (57 species) were found within peatland type FTNI.

Anthropogenic Disturbance

Based on 1989 - 1995 coverage received from Alberta Environmental Protection and a seismic line width of 15 m (a 6-8 m seismic line width is used in some sensitive areas but width was not differentiated on the available data set), total linear disturbance in peatlands only (excluding other wetlands and mineral soil) covers 2821.59 ha (15m seismic line width x 1881058.76 m of linear disturbance / 10,000 m^2) or 0.568 % of the total peatland surface area. The percent linear disturbance by peatland type ranges from 0.056% for FTPN to 0.889 % for BTNI (Table 2.6). No disturbance was present at the time for peatland type BTXN, the peatland type with the smallest surface area (96.18 ha).

If edge effect is calculated based on a 50 m and a 100 m buffer on either side of

Table 2.5. Analysis of Variance table for the nine peatland types compared ($P < 0.05$).

	SS	df	MS	F	F-crit
Between Groups	16519.44	9	1835.494	14.814	1.919
Within Groups	29736.56	240	123.902		
Total	46256.00	249			

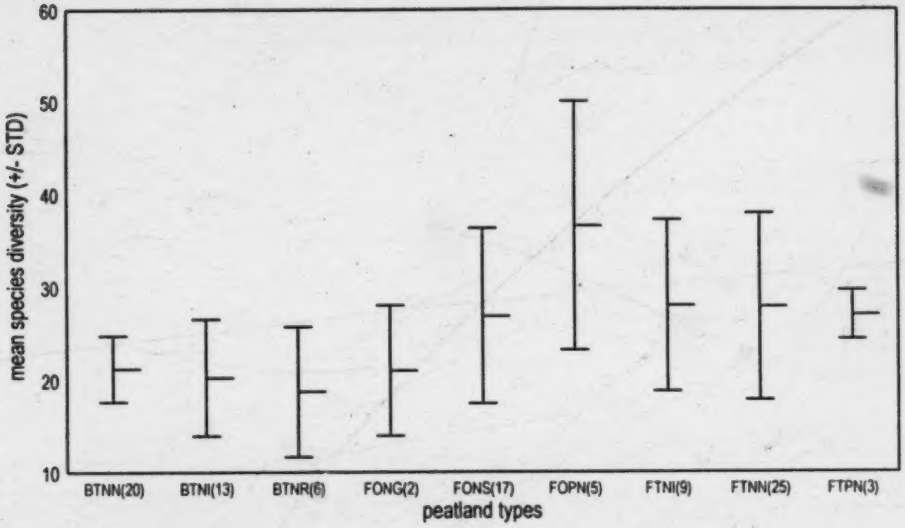

Figure 2.2. Mean species diversity (+/- STD) of the inventoried peatland types. Number in parenthesis = n.

Table 2.6. Linear disturbance length (in metres) and area based on 15 m seismic line width, with 50 m and 100 m buffer, and respective percent disturbances per peatland type and overall. B=bog, F=fen or forested, T=treed, O=open, P=patterned, X=permafrost, N=no patterning or permafrost, C=collapse scar, I=internal lawn, G=graminoid dominated, S=shrub dominated.

peatland type	peatland surface area in ha	linear dist. in metres	linear dist. area in ha	dist. area in percent	with 50 m buffer, in ha	dist. percent	with 100 m buffer, in ha	dist. percent
FTPN	2929.31	1098.81	1.65	0.056	5.49	0.19	10.99	0.38
BFXC	1022.80	878.65	1.32	0.129	4.39	0.43	8.79	0.86
FTNR	16651.41	24938.50	37.41	0.225	124.69	0.75	249.38	1.50
BTXC	747.57	1206.92	1.81	0.242	6.03	0.81	12.07	1.61
FTNN	147310.51	380246.35	570.37	0.387	1901.23	1.29	3802.46	2.58
BFXN	137.55	406.66	0.61	0.443	2.03	1.48	4.07	2.96
FTNI	46251.60	141252.21	211.88	0.458	706.26	1.53	1412.52	3.05
FONG	2343.58	7256.49	10.88	0.464	36.28	1.55	72.56	3.10
FOPN	1848.44	6039.31	9.06	0.490	30.20	1.63	60.39	3.27
FOPI	287.12	1026.30	1.54	0.536	5.13	1.79	10.26	3.57
BTNR	26069.99	108767.95	163.15	0.626	543.84	2.09	1087.68	4.17
FONS	43689.12	187924.04	281.89	0.645	939.62	2.15	1879.24	4.30
BTNN	136206.31	598212.04	897.32	0.659	2991.06	2.20	5982.12	4.39
BTNI	71142.23	421804.52	632.71	0.889	2109.02	2.96	4218.05	5.93
BTXN	96.18	no linear disturbance recorded at the time						
Totals	496637.55	1881058.76	2821.59	0.568	9405.29	1.89	18810.59	3.79

the middle of the cutline, 9405.29 ha (1.89%) and 18,810.59 ha (3.79%) are disturbed, respectively (Table 2.6). If disturbance is calculated by peatland type, percent disturbance ranges from 0.190 % to 2.96 %, and from 0.38% to 5.93, respectively (Table 2.6).

Research history

135 peatland polygons (2.2%) within Phase II area were identified as having research history.

Rare, threatened, or endangered species

Flora: Only a total of eight rare species were identified: three species of *Sphagnum*, two species of *Carex*, and three species of herbs (Table 2.7). Global rarity ranking ranges from G4 (typically > 100 occurrences but may be fewer with many large populations) to G5 (> 100 occurrences, may be rare in parts of its range, especially peripherally), and provincial rarity ranking ranges from S1 (</= 5 occurrences or only few remaining individuals) to S3 (21-100 occurrences may be rare and local throughout its range).

Fauna: Only 2 species were identified to utilize peatlands but were not linked to particular peatland types under the AWI. The woodland caribou (*Rangifer tarandus caribou*) is on Alberta's Blue List that states that *current knowledge suggests that these species may be at risk* (Alberta Environmental Protection, 1996). The woodland caribou is declared threatened under the *Provincial Wildlife Act* (Alberta Environmental Protection, 1998b). The Whooping Crane (*Grus americana*) is on Alberta's Red List that states that *current knowledge suggests that these species are at risk* (Alberta Environmental Protection, 1996).

Future Research

135 peatland polygons were identified as possible future research sites based on known research history, presence of permafrost, and presence of rare species.

Table 2.7. Plant species rarity based on Gould (1999), association with peatland type and species richness.

Species	Rank	Plots	polygon ID number	AWI type	species in plot
Carex lacustris	S2 G5	2C	5963	FONS	34
Carex rostrata	S2 G5	55	5734	FONS	18
Carex rostrata	S2 G5	67	2945	FONG	16
Carex rostrata	S2 G5	51C	6852	FTPN	28
Drosera anglica	S2 G5	52	7006	FOPN	57
Drosera anglica	S2 G5	66B	3078	FOPN	25
Drosera anglica	S2 G5	51D	7168	FOPN	39
Drosera anglica	S2 G5	51C	6852	FTPN	28
Drosera linearis	S2 G4	52	7006	FOPN	57
Sarracenia purpurea	S1S2 G5	76	9568	FTNR	27
Sarracenia purpurea	S1S2 G5	52	7006	FOPN	57
Sarracenia purpurea	S1S2 G5	43A	453	FTNN	24
Sarracenia purpurea	S1S2 G5	66B	3078	FOPN	25
Sarracenia purpurea	S1S2 G5	53B	5669	FTPN	29
Sarracenia purpurea	S1S2 G5	51D	7168	FOPN	39
Sarracenia purpurea	S1S2 G5	51C	6852	FTPN	28
Sarracenia purpurea	S1S2 G5	37	6274	FTNN	28
Sarracenia purpurea	S1S2 G5	32A	9276	FOPN	38
Sphagnum contortum	S2 G5	29	7355	FONS	52
Sphagnum contortum	S2 G5	3B	6114	FONS	27
Sphagnum fimbriatum	S2S3 G5	71B	131	BTNR	28
Sphagnum lindbergii	S2S3 G5?	63A	2589	BTNR	22

Rank (G=global; S=Alberta) in Alberta are defined as follows in Gould (1999):
G1 S1: </= 5 occurrences or only few remaining individuals.
G2 S2: 6-20 occurrences or with many individuals in fewer occurrences.
G3 S3: 21-100 occurrences may be rare and local throughout its range (may be abundant in some locations or may be vulnerable to expirtation because of some factors because of its biology).
G4 S4: apparently secure under present conditions, typically > 100 occurrences but may be fewer with many large populations; may be rare in parts of its range, especially peripherally.
G5 S5: demonstrably secure under present conditions, > 100 occurrences, may be rare in parts of its range, especially peripherally. (G5? = not yet ranked)

MANAGEMENT RECOMMENDATIONS & DISCUSSION

Introduction to Peatland Management Key

The peatland management key (Table 2.8, Fig. 2.3) is a dichotomous key that consists of 17 decision points or couplets soliciting yes or no answers. Up to decision couplet 8 for intermediate peatland types and 9 for common peatland types no on-ground site assessment is necessary. At couplets 8 and 9 respectively a site visit becomes necessary to ascertain presence of rare species and diversity. While species rarity and plant diversity is ascertained in the field, horticultural peat harvesting potential can be ascertained at the same time. It is obvious that a peat company would not allocate resources for a rare species assessment without establishing peat quality and therefore economic potential first. Hence, peat companies are not forced to assess ecological values on sites they are not interested in. However, if a company identified a site for development and the site assessment by a professional plant ecologist or botanists shows that rare species are present or the species diversity is high, then the company would be asked to provide this information so that the site can be identified for conservation.

The decision key is accompanied by a text that explains each decision couplets in more detail. The text is meant to supplement the key and clarify points. Each criterion used in the key is discussed in more detail later.

Table 2.8. Peatland Management Key, text part.

How to use the key: Each vertical line is associated with a decision question and a number. The number links the key to the text below that explains each decision couplet in more detail. Decision rules consist of yes/no questions only. Terms like rare, common, or intermediate are explained in the text below and are thoroughly discussed in the document.

Decision rules:

1) Peatland type rarity is based on the GIS data base and can be obtained from Table 2.4. Peatland types BTXN, BFXN, FOPI, BTXC, BFXC, FOPN, FONG, FTPN, and FTNR are considered rare because they represent either less than 3.5 % of the total peatland area or less than 2 % of the total number of polygons. All the above peatland types should be protected from development and identified in the GIS data base. If the peatland type is not rare, go to decision 2; if rare, go to 3.

2) Peatlands types that are intermediate in rarity are BTNR, FONS, FTNI, and BTNI because they represent either > 3.5% but < 20 % of the total peatland area or > 2% but < 20 % of the total number of polygons. If the peatland type is intermediate in rarity go to the right (y); if not, go to the left (n) .

3) All rare peatland types should be conserved because they represent only a small portion (< 3.5 % area) of the total peatland types. Four of the 8 peatland types have permafrost present, 1 has internal lawns, 2 are patterned, and 1 type is graminoid dominated. The significance of permafrost, and peatland ecology in general, are discussed in the text.

Rare peatland types should be identified in the GIS data base to conserve them. They represent 5.25% of the total peatland area.

4) Peatlands identified as caribou habitat by the Boreal Caribou Research Committee should be conserved so that the habitat is maintained. The Alberta Government issued an information letter (IL 91-17) that states that industrial activity can continue on caribou range "providing the integrity of the habitat is maintained to support its use by caribou" (Alberta Energy 1991). Horticultural peat harvesting or removal of vegetation for other purposes does alter peatland ecology and affect habitat and habitat quality. Contact the BCRC for management recommendations, also see decision 7.

5) Peatlands that have </= 2% linear (or other anthropogenic) disturbance per polygon should be conserved. Linear disturbance here is calculated without buffers. Most peatlands in boreal Alberta been impacted by seismic exploration (over 1,881 km of linear disturbance in the peatlands within the study area) and to only select pristine peatlands would probably exclude too many peatlands from protection. If the peatlands have =/< 2.0% disturbance conserve; if > 2 % disturbance go to 8. The percent disturbance per peatland polygon must be obtained from the GIS data base. It was not available at the time of the study. However, a small subsample of approximately 2% of polygons suggested a 2% cut-off. If disturbance per polygon is =/< 2% go to the left (y), conserve; if > 2% go to the right (n), decision 8.

6) as above - if yes, conserve; if no, go to 9.

7) The BCRC, in consultation with the peat industry, is in the process of developing management recommendations for peatlands within caribou range. Contact the BCRC for details.

8) Peatlands that provide habitat for rare, threatened, or endangered organisms, have a potentially high species diversity (see Fig. 3), have an established research history, or have potential as future research sites should be conserved. **A site visit is necessary to assess species rarity and diversity.** If the sites have rare species or a high species diversity, the peatland polygon should be identified on the GIS data base and rare species should be reported to ANHIC (flora) or Alberta Fish and Wildlife (fauna).

Sites that have permafrost present or signs of former permafrost may be important research sites in respect to changing climate studies (see text).

9) as in 8)

10) Not all of the identified sites or peatland types are suitable for peat harvesting. At this couplet (decision point), sites with high ecological and/or research values are excluded from potential harvesting sites. All peatland types that are identified following the decision key should belong to one of the following peatland types: BTNR, FONS, FTNI, and BTNI. Such peatland types are generally not the preferred peatland types for horticultural peat.

11) Unlike in decision 10 above, peatland types that are identified here are common and only include FTNN and BTNN.

Bogs, BTNN, have the desired weakly decomposed *Sphagnum fuscum* peat and are easily identified on the GIS data base or the hard copy maps. Treed fens on the other hand range from poor fens to intermediate rich (in the study area, may be extreme rich in other areas in Alberta) but only poor fens provide *S. fuscum* peat. All treed fens are mapped as FTNN and it is not possible to identify horticultural peat harvesting potential in the GIS data base or the maps. Poor fens can be easily and quickly identified on ground.

12) Conserve the peatlands and identify in the GIS peatland layer data base as conserved. If rare species are present, notify applicable authority: ANHIC for flora and Alberta Fish and Wildlife for fauna. Sites with research history and/or research potential should be identified in the data base for long term management planning.

13) Peatlands that are not suitable for development should be identified for conservation and their surface area and the number of polygons per type, as well as overall, should be calculated. Peatlands identified for conservation or development must be included in a proper management plan.

14) as above in 13).

15) Peatlands that have been identified as having harvesting potential should be identified in the GIS data base for long term management plans. Of the selected sites, identified polygons that meet conditions b - d and calculate the amount of peatland. The total area and the total number of polygons, as well as area and the number of polygons per peatland type, their geographic locations within Alberta's subregions and within the study area, should be assessed. Please note, subregion boundaries were not overlain on the peatland layer and were not available at the time of the study but it is recommended, see recommendation section.

Once the amount of peatland that met conditions b - e is calculated, answer question 15. The cutoff is 45% in relation to either peatland surface area or to the number of polygons per peatland type, whichever is higher. Forty-five percent is an arbitrary number chosen, but see p. 50.

If > 45% per peatland type are identified, the conditions under 15) have to be applied more stringently; e.g. sites should be closer to roads or sites have to have a larger degree of disturbance. GIS analysis should be applied to answer question 15 efficiently and reliably.

16) Sites that are found suitable by the above process and are desired by industry should be assessed on ground for rare fauna and/or flora by a professional biologist. Other assessments such as EIA or CEA are not discussed in this document.

Peatlands that have been identified as having horticultural peat harvesting potential have not been checked for peat volumes or quality. The selection process only addressed the separation of the most ecological valued peatlands from those that are less valued under the criteria and methods introduced earlier in the document.

17) See 15).

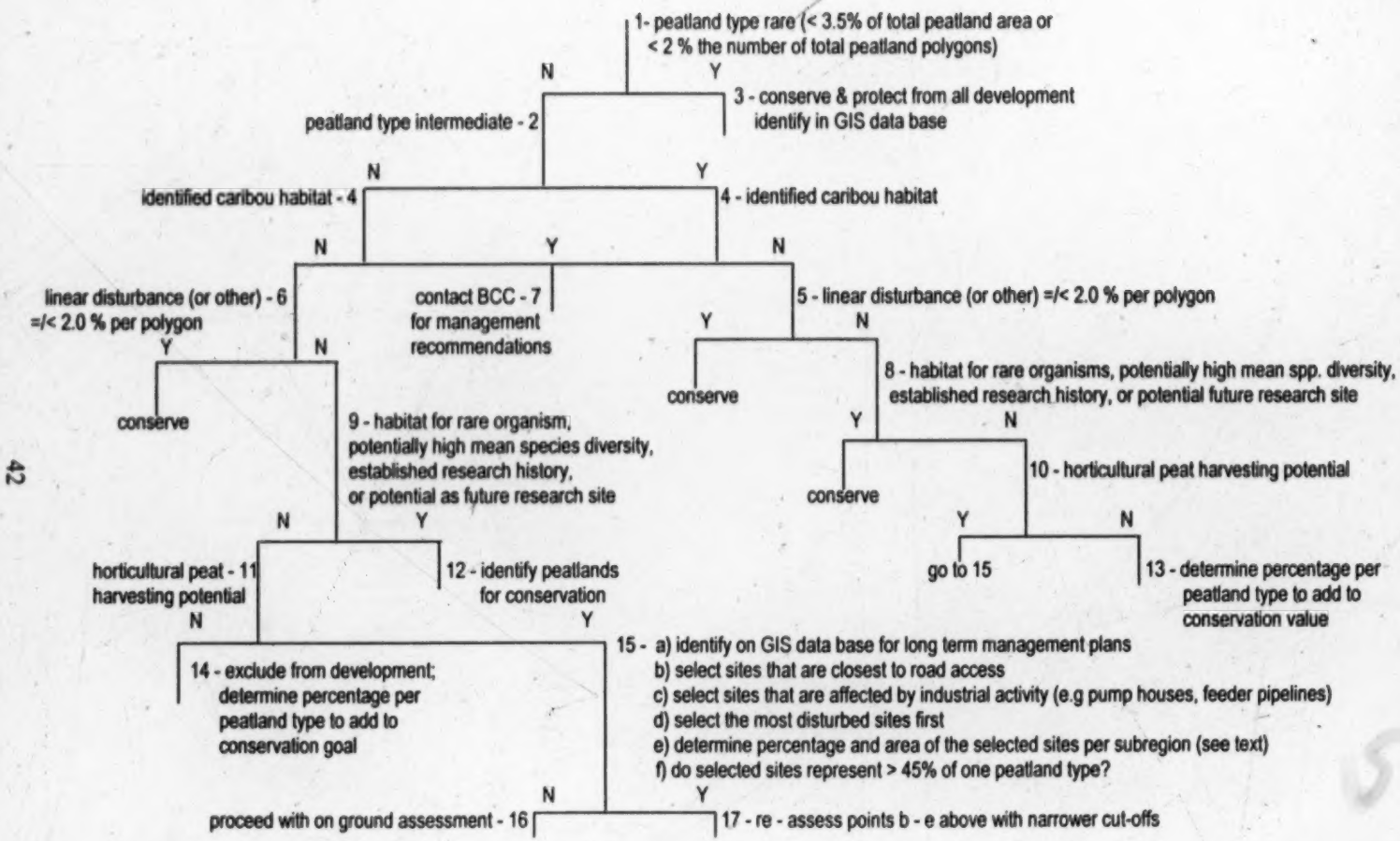

Figure 2.3. Peatland Management Decision Key. See text Table 2.8.

Relative Peatland Type Abundance within Phase II Study Area

Fifteen different peatland types totaling 6,119 peatland polygons larger than 0.5 ha were inventoried. Polygons smaller than 0.5 ha were excluded because of mapping limitations at the 1:50,000 scale. A 0.5 ha square area would be a square area of 0.141 x 0.141 cm on the map and a square area of 70.71 x 70.71 m on the ground.

Rarity of peatland type polygons in this study was based on the GIS data base generated by landscape scale mapping and AWI inventory and not on an ecosystem classification for ground surveys that would differentiate peatlands on a finer ecological scale. Remote sensing was applied because of the sheer size and inaccessibility of Alberta's peatlands.

When ranking peatland types by commonness or rarity, they can be ranked by size of surface area per type or by number of polygons per type. Surface area may be important when considering a peatland's rate of carbon sequestering whereas the number of polygons may not matter. The number of polygons may be important for species that can only live in the narrow margins between peatlands or peatland and mineral soil whereas the actual size of the peatland may not be important. From an ecological perspective it is not known if surface area or the number of polygons is more important. Because both parameters could be used, an algorithm should specify that the smaller value, polygon number or surface area, should be used.

Within the study area, the most common peatland types are treed fens (FTNN) and bogs (BTNN). BTNNs are the most common type by polygon number and FTNN by surface area.

The rankings given below refer to the relative number of polygons, followed in brackets by the relative size (rank by size) and the actual surface area. The rarest peatland type, ranked as 1 (3; 2.87 km^2), is the open, patterned fen category with internal lawns (FOPI), with a total of 2 polygons. In the AWI (Halsey & Vitt, 1996), open patterned fens are given as peatland types; however, they are never associated with internal lawns. Hence, the combination of FOPI never appears in the AWI. This may very well be

because of the rarity of this landscape pattern; it only represents 0.033% of the total peatland polygons. Additionally, the definition of wooded (>6% to 70% tree cover, T, rather than <6% tree cover, O) may pose a problem at times when employing aerial photograph interpretation as a tool to inventory peatlands. Trees may have been present at an abundance of > 6%, but they may have been rather small and therefore not visible on 1:40,000 or 1:20,000 scale aerial photographs (the two scales generally used in this study).

For the purpose of evaluating relative peatland type rarity, FOPI is the rarest peatland type and should therefore receive the highest rarity rating. Rather than associating this type with a ranking number or an algorithm that determines how many of this type should be conserved, both FOPI polygons should be identified for conservation.

The second rarest peatland type is BTXN (1; 0.96 km^2) with a total of only 3 polygons or 0.019 % of the total peatland polygons. Peatland type BTXN shows no permafrost degradation although most peatlands in Alberta that are underlain by permafrost are associated with degradation (having internal lawns, I, or collapse scars, C) that is easily recognized on aerial photographs. Signs of permafrost and permafrost degradation are common within the upper one third of the study area but not the peatland type BTXN. Because of the relative rarity of the type, all three BTNX peatlands should be identified for conservation.

In general, permafrost underlain peatlands (peat plateaus) may add to habitat heterogeneity within the landscape and act as islands within other, non-permafrost underlain peatlands. Peat plateaus rise above other peatland surfaces due to the expansion of the permafrost and are therefore drier. Such communities are ecologically more similar to upland black spruce than to typical peatland communities that are associated with species of *Sphagnum*, acidic, anoxic, and wet conditions. *P. mariana* communities on peat plateaus are associated with feathermosses and a duff layer composed of needle litter and small twigs typical of a *P. mariana* forest on mineral soil.

It is also noteworthy that squirrel middens in peatlands were only found on permafrost underlain peatlands and not on any other peatland types. Large owl pellets

were also retrieved on one permafrost mount but their composition was not identified.

Perhaps the above suggests that permafrost mounts may provide habitat for red squirrels, and that red squirrels may select such habitat because of the relative freedom from predators similar to what is suspected of larger ungulate behaviour (Bergerud et al. 1990). Unfortunately it was not possible to identify the contents of the owl pellets and it is unknown if the diet of the owl consisted of red squirrel. Neither was it possible to positively associate the pellets with an owl species, but pellet size suggested a larger owl (pers. comm. B. Olsen).

The third rarest peatland type is BFXN (2, 1.38 km^2) with a total of only 11 polygons or 0.18% of the total peatland polygons. The only difference between the BTNX and the BFXN category is that the latter has > 70% crown closure. Conservation considerations for rare peatlands should apply.

The fourth rarest peatland type is BTXC (4, 7.48 km^2) with a total of 36 polygons or only 0.59% of the total peatland polygons. This bog type is associated with collapse scars typical of permafrost degradation. The peatland type is considered rare and should be conserved.

The fifth rarest peatland type is FTPN (8; 29.29 km^2) with a total of 47 polygons or 0.77 % of the total peatland polygons. Treed patterned fens are relatively rare considering that they do not even contribute one percent to the total number of peatland polygons.

The sixth rarest peatland type is BFXC (5; 10.23 km^2) with a total of 53 polygons or only 0.87% of the total peatland polygons. This peatland type has a closed canopy (< 70% tree coverage) and is associated with collapse scars typical of permafrost degradation. The peatland type, along with other permafrost underlain peatland types mentioned above, may be important in climate change studies because collapse scars (and internal lawns) may be useful in aging the beginning of climate change (warming) and possibly in monitoring rate of change. The peatland type does not even contribute one percent to the total number of peatland polygons and should be considered rare.

The seventh rarest peatland type is FOPN (6; 18.48 km^2) with a total of 56

polygons or 0.92 % of the total peatland polygons. Open patterned fens are relatively rare considering that they do not even contribute one percent to the total number of peatland polygons. The peatland type has less than 6% tree coverage but may be dominated by sedges, grasses, shrubs, herbs, and/or a bryophyte layer or a combination of these groups. The peatland type contributes less than one percent to the total number of peatland polygons and should be considered rare.

The eighth rarest peatland type is FTNR (9; 166.51km^2) with a total of 120 polygons or 1.96 % of the total peatland polygons. The surface water flow can be very obvious on aerial photograph and sometimes at the ground level in these treed fens that have islands of peat plateaus. The peatland type contributes just under 2 % to the total number of peatland polygons but over 3% of the total peatland area and may be considered rare.

The ninth rarest peatland type is FONG (7; 23.44 km^2) with a total of 178 polygons or 2.91 % of the total peatland polygons. This fen type is graminoid dominated, most often by sedges. The peatland type contributes just under 3 % to the total number of peatland polygons but less than 0.5 % of the total peatland area and can therefore be considered rare.

The tenth rarest peatland type is BTNR (10; 260.70 km^2) with a total of 189 polygons or 3.09 % of the total peatland polygons. The peatland type contributes over 3.0 % to the total number of peatland polygons but over 5.2 % of the total peatland area and can therefore be considered intermediate in rarity.

Ranked as eleventh peatland type in respect to abundance is FTNI (12; 462.52 km^2), with a total of 245 polygons or 4.00 % of the total peatland polygons. Internal lawns are the last signs of completely degraded permafrost, here within a treed fen matrix. FTNI contribute 9.31 % of the total peatland area and can therefore be considered intermediate in rarity.

Ranked as twelfth peatland type in respect to abundance is BTNI (13; 711.42 km^2), with a total of 319 polygons or 5.21 % of the total peatland polygons. Internal lawns are the last signs of completely degraded permafrost, here within a treed bog

matrix. BTNI contribute 14.33 % of the total peatland area and can therefore not be considered rare in respect to abundance but should be in the intermediate to common ranking category.

Ranked thirteenth in abundance are FONS (11; 436.89 km^2) with a total of 1198 polygons or 19.58 % of the total peatland polygons. Open shrubby fens are very common throughout the study area but only contribute 8.79 % of the total peatland area. They can be considered intermediate in rarity.

Ranked fourteenth in abundance is the FTNN peatland type (15; 1473.11 km^2) with a total of 1415 polygons or 23.12 % of the total peatland polygons. Treed fens cover a slightly larger area than bogs (by 111.05 km^2) but have a much lower number of polygons (832 polygons less than bogs) which suggests that the individual polygons are larger than the bog polygons. FTNN peatland types can not be considered rare by either surface area or by number of polygon occurrences.

Ranked fifteenth in abundance is the BTNN peatland type (14; 1362.06 km^2) with a total of 2247 polygons or 36.72 % of the total peatland polygons. Bogs cover a slightly smaller area than fens (by 111.05 km^2) but have a much higher number of polygons (832 more polygons than fens) which suggests that the individual polygons are smaller. BTNN peatland types can not be considered rare by either surface area or number of polygon occurrences.

Algorithm:

Also refer to Peatland Management Key for complete overview.

1) All peatlands that represent less than 3.5 % by peatland surface area or less than 2 % by number of polygons by peatland type are considered rare. The cut-offs were chosen because percent peatland distribution shows breaks between rare and intermediate peatland types by surface area (Fig. 2.4) and to a lesser degree by total number of polygons (Fig. 2.5, also see Table 2.4). Peatland types FTNR and BTNR are similar in abundance by surface area and the natural break seems to appear between types FTNR and FTPN (Fig. 2.4), when peatland type rarity is assessed by number of polygons, the natural breaks differ again. Peatland type FTNR is now rarer than FONG, whereas

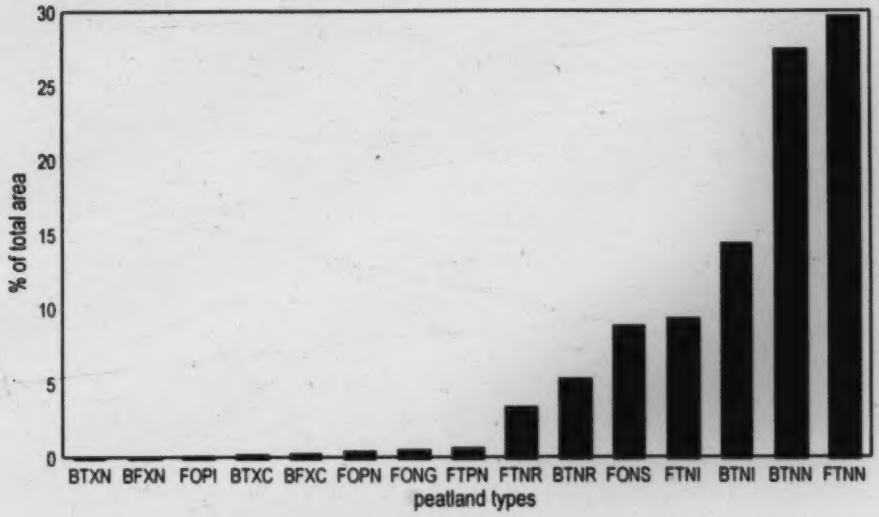

Figure 2.4. Percent peatland distribution by surface area.

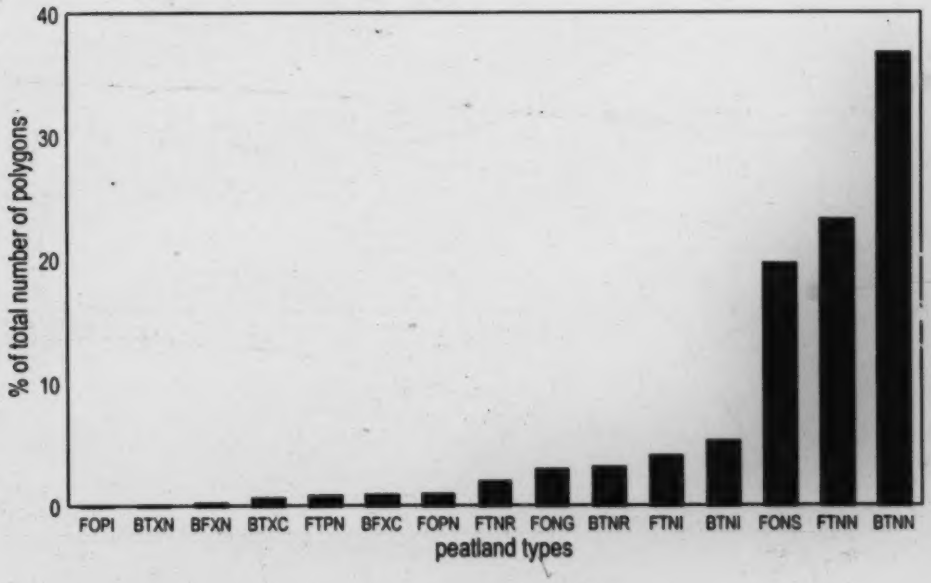

Figure 2.5. Percent peatland distribution by total number of polygons.

FONG is rarer than FTNR by surface area (Fig. 2.4 and 2.5). It is not clear if several smaller polygons are more important that a few large ones and the percent cut-off levels were chosen based on the combination of the two parameters. Cut-off levels can not be tested statistically because there are no comparable data, especially not for Alberta's Boreal Forest landscape, and no data that compare number of polygons versa area could be found.

In 1987 the World Commission on Environment and Development indicated that approximately 12% of the landscape should be conserved and in 1991 the Canadian Environmental Advisory Council recommended that large areas in the order of 4,000 km^2 are needed for complete wilderness and biodiversity protection. It is not clear which percentage of peatlands should be conserved, but to protect landscape heterogeneity rare peatlands should be conserved.

The above rare peatlands should be excluded from peat extractions (e.g. horticultural, fuel peat extraction), drainage for cattle grazing or forestry, or habitat fragmentation (e.g. seismic exploration, pipelines, surface disturbance of in-situ operations) because only if these rare peatlands are protected can one ensure adequate representation of Alberta's natural diversity. The above rare peatlands represent 0.074% of the green area and 2.08% of the study area.

2) Peatlands that represent either over 3.5 % but less than 20 % of the total peatland area or more than 2% but less than 20% of the total number of polygons area are considered intermediate in rarity. A certain percentage of these peatland types should be conserved to represent the Boreal Forest landscape and Alberta's natural diversity. Intermediate rare peatland types that have less than or equal to 2% disturbance, or provide habitats for rare organisms, have a potentially high species diversity, have an established research history, and/or potential as future research sites should be selected as conservation candidates.

Based on the recommendation by the World Commission on Environment and Development (1987) and the Canadian Environmental Advisory Council (1991) a portion of the intermediate rare peatlands should be conserved. It is recommended that 55% of the intermediate peatland types should be identified for conservation because the

percentage represents 0.29% of the green area and 8.20% of the study area but less than the recommended 12% of the landscape.

3) Peatlands that represent more than or equal to 20 % by peatland surface area or by number of polygons by peatland type are considered common. Although common, it should be remembered that responsible resource management must address ecosystem sustainability and function, especially peatland hydrology and carbon storage.

For the above reasons, in addition to maintaining the heterogeneity of the Boreal Forest landscape, only a portion of the two peatland types should be allowed for resource extraction while the remaining FTNN and BTNN should be conserved.

Peatlands chosen for conservation can be chosen for multiple criteria and the same polygons may be chosen for several criteria. For example, peatlands chosen for protection from anthropogenic disturbance may also be chosen to include key caribou habitat, rare species habitat, high diversity polygons, or sites with high research history.

In the management key, only 45% of peatlands that meet the criteria of couplet 15 can be developed, but the actual peatland area that can be selected for development or conservation is not known until ground surveys are conducted and peat companies have selected appropriate sites. Common peatland types represent 0.44% of the green area and 12.42% of the study area. Economic development by peat industry would not be curtailed by imposing a 45% limit. Forty-five percent of the common peatland types in the study area encompass 70,170.3 ha. Currently, only 1,800 ha within the entire green area are developed by the peat industry, and a horticultural peat plant generally stays on site for 20-30 years (Tony Cable, pers. com.).

It is clear that currently horticultural peat extractions alone are not the primary concern in peatland management but rather the future combined effect of horticultural peat companies and hydrocarbon industry. The hydrocarbon industry leaves the largest footprint in the Boreal Forest at this time, but as peat companies move farther north their impact must be taken into consideration as well. It is important for the peat industry to avoid depleting bogs close to transportation routes in the southern portion of the green area. Otherwise ecological representation of the landscape can not be sustained.

Overall, the total recommended area for conservation within the study area is 22.69%, but a) it must be remembered that the area was chosen because of its abundance of peat, and b) that peatlands may be managed in different geographic units in the future. The study area does not correspond to a natural subregion that is identified by its biophysical attributes but is identified by township boundaries. It would be ecologically meaningful to adopt natural subregions as peatland management region.

Most regions outside the study area but within the green area have fewer peatlands and conservation recommendations, especially the amount of peatlands that should be conserved, would be lower. Thus, the percentage of peatland that is protected within the study area can not be used to extrapolate the amount of peatland that would be conserved in the entire green area. Regions outside the study area have often considerable fewer peatlands, this is especially true for the Foothills Natural Region where peatlands only represent 7.48% of the entire landscape (Vitt et al., 1996) compared to the study area where peatlands represent 39.56% of the landscape.

Species diversity

The term "biodiversity" has been defined by many authors and is reviewed by Gaston (1996), who also stated that it is simply a synonym for "variety of life". Here it is used as species' richness or number of species.

Flora:

A boreal peatland's signature is not diversity but unique habitat created by low temperatures, high precipitation, and distinct surface water. In western Canada, 109 bryophyte species can be expected in peatlands, of which there are 64 mosses, 26 hepatics, and 20 *Sphagnum* (Vitt et al., 1995). Extreme rich fens were the most diverse peatland type (67 species), peat plateaus and poor fens were somewhat poorer (44 species each), while moderate rich fens and continental bogs were the species poorest (35 and 36 species respectively) (Vitt & Belland, 1997). Fifty-six percent of the species found in peatlands were restricted to only one peatland type (Vitt & Belland, 1997).

Biodiversity in peatlands has largely been studied as bryophyte diversity (Belland

& Vitt, 1995; Vitt et al., 1995; Vitt & Belland, 1997). Bryophytes are important indicators of water chemistry (pH, alkalinity, cation exchange capacity, conductivity) and moisture levels, while vascular plants are important indicators of nutrients, especially nitrogen and phosphorus (Vitt & Chee, 1990). Hence, bryophytes are excellent indicators of change and peatland condition.

Bryophyte diversity in peatlands is largely determined by habitat heterogeneity (Belland & Vitt, 1997; Vitt et al., 1995), generally following chemical and moisture gradients. Bryophyte species diversity in poor fens and extreme-rich fens is also affected by pH, but not in the other peatland types such as bogs or intermediate-rich fens.

Habitat heterogeneity in peatlands can be attributed to several peatland and landform features. Permafrost collapse and the following successional changes generate a gradient of habitats. Initially, collapse scars and internal lawns are very wet but become drier as succession proceeds. Simultaneously, light conditions change when the usually tall, dense conifers tilt with subsidence. In the early, very wet successional stages internal lawns are exposed but conifers will establish themselves again in the late successional stages. Hence, peatlands that have or had permafrost have a higher potential for number of habitats compared to relatively homogeneous fens or continental bogs. Patterned fens have the potential to have more microhabitats because of the wet to dry gradient generated by strings and flarks; other less obvious microhabitats may include hummocks, hummock sides, lawns, carpets, pools, tree bases, shades tree base depressions, humidified peat, and forest duff (Vitt et al., 1995).

If biodiversity is a critical factor in site selection for conservation, Vitt et al. (1995) recommended that models should be based on peatland type, habitat heterogeneity and pH. While pH and direct habitat heterogeneity can not be measured using the landscape scale approach, one can extrapolate species diversity based on mapped peatland types and the number and types of sites sampled.

Within the Phase II study area, 123 plots were ground inventoried for species richness (see Chapter 3, Forest, 2000) but twenty-two plots were eliminated because the plots were located in peatlands that were too small for the mapping scale of 1:50,000.

Within the remainder, the mean species number was calculated for each peatland type as mapped in the AWI inventory. It is important to note that because of mapping scale and landscape heterogeneity at the ground level, peatland types were not always identified on the ground as the same as in the inventory (discussed in Chapter 3). It is for this reason too, that data are only available for 10 peatland types instead of the 15 mapped. However, the peatland type designation from the GIS data base was taken for the purpose of this evaluation. Actual site information was linked to the mapped data base by entering the UTM coordinates.

The data show that FOPN has the highest mean species occurrence (36.6) by far, followed by FTNI (28.0), FTNN (27.9), FTNR (27), FTPN (27), FONS (26.9), BTNR (21.8), BTNN (21.2), FONG (21), and BTNI (20.2) (Fig. 2.3). Because not all peatland types are represented it is difficult to evaluate conservation in respect to biological diversity. It should be recognized that a peatland type that has more species (higher biodiversity) may not necessarily be more valuable ecologically because these data only represent vascular plants, bryophytes and lichens and not groups such as invertebrates.

Algorithm:

1) Select peatland types with the highest mean species richness first. While data from this study showed a mean species richness of 26.9 and a range of 10 to 57 species, selection of peatlands for management and conservation purposes must be taken from the number of peatlands in questions. Here it is assumed that peatlands are selected for management purposes and that they may be different than the sample set.

2) From the above, select 55 % of all polygons for conservation. By selecting at least 55%, the chances of representing sites with high species richness are better. By taking a coarse-filter approach species that were not sampled on the landscape may be conserved.

3) Select at least the same number of polygons for each of the other peatland types to ensure representation of the landscape and all ecological niches, as well as all other organisms.

Invertebrates:

Invertebrates are probably the most diverse and least known group of peatland species which prompted *The Biological Survey of Canada* to initiate two projects: *Aquatic Insects of Peatlands and Marshes* (1987) and *Terrestrial Arthropods of Peatlands* (1994).

Both projects demonstrated that invertebrates greatly contribute to the biodiversity of peatlands. Finnamore's study (1994) at Wagner Natural Area (a boreal spring fen) in central Alberta yielded 1,410 species of Hymenoptera (bees, wasps, bumble bees), but he estimated the total to be 6,000 species of arthropods! Other studies of terrestrial invertebrates in peatlands found 40 species of Odonata (dragonflies) (Cannings & Cannings, 1994), 71 species of Oribatida (mites) (Behan-Pelletier & Bissett, 1994), and 169 species of Arachnida (spiders) (Koponen, 1994).

Studies of aquatic insects showed similar results. Rosenberg and Danks (1987) calculated (from Ryan & Hilchie, 1980) the numbers of larval Chironomidae (midges) in a northern Alberta fen to be 12,474/m^2. A total of 104 species of Chironomidae (Wrubleski, 1987), 75 species of immature Odonata (Hilton, 1987), and 465 species of Coleoptera (beetles) are known from marshes, fens and bogs (Larson, 1987).

The problem that was identified by Rosenberg and Danks (1987) during the study of *Aquatic Insects of Peatlands and Marshes* was the inconsistency of wetland terminology. It was not always clear if inventoried invertebrates were peatland obligates or generalists, and perhaps even more importantly what type of wetland they were from. Nevertheless, both surveys showed that peatland invertebrate diversity is rather large and should be of importance in peatland management and conservation.

Unknown species diversity (or rarity) may be protected by the coarse-filter approach of point 3 of the above algorithm. By selecting representative of the landscape for protection, regardless of species diversity or rarity, most possible ecological niches and their organisms are conserved.

Avifauna & others:

Peatlands provide habitat for the endangered Whooping Cranes that are only known to breed in Wood Buffalo National Park, but utilize other peatlands when migrating through the prairies (Alberta Environmental Protection, 1996). It is known that species such as Sandhill Cranes, Sharp-tailed Grouse, Greater and Lesser Yellowlegs, some warblers and sparrows are known to utilize peatlands based on breeding bird surveys (Francis & Lumbis, 1980), but no in-depth studies exist that link species habitat to peatland types. This is especially true for central Alberta peatlands where access is only possibly by helicopter but where the landscape is often dominated by peatlands. Neither has there been an in-depth study of micro-organisms, reptiles, amphibians, or mammals that was linked to peatland types.

Rare, threatened, or endangered species

A number of species in Alberta are on tracking lists because their populations are small or declining. Flora is tracked by the *Alberta Natural Heritage Information Centre* (*Natural Resources Service*) and fauna is tracked by the *Wildlife Management Division* (*Natural Resources Service).*

Flora: Belland and Vitt (1995) considered 45 species rare in continental Canadian peatlands. Rarity was based on species occurrences in 2 or less sites in the 100 peatlands surveyed. Not only did their study show that 27 species (25%) occurred at only one site and 18 species (16%) occurred at 2 sites, but also that 15 species (52%) were restricted to 1 peatland class. Of the 27 species, 15 species were restricted to extreme-rich fens, 5 species to poor fens, 4 species to continental bogs, 2 species to peat plateaus, and 1 species to moderate-rich fens.

If rarity is determined by species occurrences at 1 to 5 locations (used by ANHIC and the Nature Conservancy) based on herbarium records, the number of rare species in peatlands is reduced to 10. Vitt & Belland (1997) showed that bryophyte rarity in peatlands is restricted to rich fens (7 species) and *Sphagnum*-dominated systems (3

species). There are no conclusive studies in respect to vascular plant rarity.

Of the sites and peatland types surveyed, seven peatland types, BTNR, FTNN, FONG, FOPN, FTPN, FONS, and FTNR had rare plant species present (Table 2.7). Only a total of eight rare species were identified following the methodology applied by ANHIC: three species of *Sphagnum*, two species of *Carex*, and three species of herbs (Table 2.7).

While *Carex rostrata* and *C. lacustris* are not necessarily restricted to peatlands (but other wetlands types as well), the *Sphagnum* species, *Drosera anglica, D. linearis*, and *Sarracenia purpurea* are peatland obligates. All three carnivorous plants are well adapted to peatlands and generally prefer nutrient poor habitats and utilize insects to meet their nutrient requirement (Juniper et al., 1989). The Droseraceae and Sarraceniaceae are calcifuges (i.e. plants with low calcium requirements that can live in an environment that has a pH of 4 or less) and inhabit wet, infertile grounds such as in bogs and fens (Juniper et al., 1989). Carnivorous plants are usually tolerant of nutrient poor soils but intolerant of desiccation and shading (Juniper et al; 1989). Their ecological niche allows them to utilize peatlands but also restricts them to habitats where there is little space competition from other vegetation. In the case of *D. linearis*, a *Sphagnum* lawn that is saturated but not flooded seems to be the preferred habitat (pers. obs.). Presumably the water-saturated *Sphagnum* lawn, and possibly water chemistry, restricts other plant growth and therefore competition. Like most rare plants, they are rare because their habitats, or their ecological niche, are limited. Habitat rarity, perhaps combined with other factors such as dispersal, establishment, and reproduction, more than likely limits all rare species. Because of habitat rarity, potential rare plant habitats should be conserved to assure the existence of viable populations.

Algorithm:

1) Conserve all peatland polygons that were identified as having rare species present.

2) It is next to impossible to ground survey all these peatland types and therefore a coarse-filter conservation approach is suggested. Conserve at least 55% of the peatland types that we know provide potential rare species habitat. By conserving at least 55% of

these peatland types, a number of potentially rare habitats and the associated species are conserved.

3) Select at least the same number of polygons for each of all the other peatland types to ensure representation of the landscape and all ecological niches.

Fauna: One ungulate known to utilize peatlands is the woodland caribou (*Rangifer tarandus caribou*). Woodland caribou are on Alberta's blue list and are designated as threatened under the *Provincial Wildlife Act* (Alberta Environmental Protection, 1998b). The designation may indicate a species at risk of declining to a non-viable population (Alberta Wildlife Management Division, 1996). In 1996, the Alberta population was estimated to be 3,500 individuals but declining (Alberta Environmental Protection, 1996).

Caribou are known to utilize peatlands for food and shelter (Bradshaw et al., 1995) and feed predominantly on deciduous, leafy material in spring/summer and on lichens in winter (Darby & Duquette, 1986; Godwin, 1990). Bradshaw et al. (1995) showed that herds east of the foothills select peatlands over uplands and a recent study by Anderson (1999) showed that woodland caribou within Phase II study area preferred treed fens and bogs over other habitat classes throughout the year.

Because woodland caribou is a threatened species its habitat should be conserved to ensure that viable populations are maintained. From a peatland management point of view, treed bogs and fens within woodland caribou range must receive special attention. It would be too simple to suggest to conserve all treed peatlands within caribou range, but instead it is suggested to consult with the Boreal Caribou Research Program (also see information letter IL 91-17 (Alberta Energy, 1991) and Anthropogenic Disturbance) and to review the management recommendations by Anderson (1999) and Dyer (1999).

Peatlands provide habitat for the endangered Whooping Cranes that are only known to breed in Wood Buffalo National Park, but utilize other peatlands when migrating through the prairies (Alberta Environmental Protection, 1996). Once a known migration route is mapped, peatlands along the flight pass can be protected from permanent anthropogenic disturbances, and from disturbances such as vehicle traffic

during migration.

Algorithm:

1) Conserve all known caribou habitat as defined by Alberta Environment and/or BCC and/or refer to management recommendations by the BCC.

2) Conserve all peatlands that are utilized by Whooping Crane during migration - consult with the Canadian Wildlife Service.

3) Conserve at least 55% of all peatland types. By conserving at least 55% of these peatland types, most potentially rare habitats and the associated species are conserved. A coarse-filter conservation approach may be the only possible approach in landscape scale conservation.

Anthropogenic Disturbance

Linear disturbance features not only fragment habitats but also create an edge effect. An edge allows for invasive species to establish themselves, infiltrate the peatland matrix for a distance from the edge, and change the microclimate and species assemblage. In addition, seismic lines also affect hydrology (Fig. 2.6). Because of peat compaction, seismic lines are lower than the surrounding peatland surface (can be 15-20 cm or more, pers. obs.) and act as drainage channels. They drain water from the peatland on either side and channel it in the direction of the natural water flow. In some instances, vegetation typical of marshes (e.g. *Cicuta maculata*) has been observed in a seismic line cut through a treed poor fen (pers. obs.). Physiognomy data showed that the cutline was 65% covered with water compared to the adjacent undisturbed peatland plot that had a water physiognomy value of 1%. Belland & Vitt (1995) showed that the most important environmental factor determining bryophyte distribution in continental bogs are dryness and shade. When a seismic line is cut, hummocks are flattened that results in the removal of habitat heterogeneity created by the wet-dry gradient on hummocks. Tree removal interrupts shade loving and tolerant vegetation that was naturally established in its ecological niche. Hence, seismic lines can interfere with the most important factor that influences bryophyte distribution.

Fig. 2.6. Cutline through a peatland in northeastern Alberta.

Mammals are known to avoid linear disturbance corridors over a range of 100 m to over 1,600 m (Dyer, 1999; Jalkotzky et al., 1997). In order to maintain habitat integrity and quality, the edge effect should be considered in management plans. The problem can be addressed by allowing buffers along linear disturbance corridors to calculate quality habitat or amount of indirect disturbance (edge effect).

If one uses a conservative buffer of 50m (25m on either side of the middle of the cutline) 9,405.29 ha or 1.89 % of peatlands are affected by disturbance (Table 2.6). If disturbance is calculated by peatland type, the percent disturbance ranges from 5.49 ha (FTPN) to 2991.06 ha (BTNN) (Table 2.6). Anderson (1999) showed that BTNN and FTNN peatland types are preferred caribou habitats and Dyer (1999) showed that caribou do avoid linear disturbances. With a conservative buffer of 50 m, a substantial amount of peatland are affected.

A 50 m buffer seems relatively conservative based on recent caribou data (Dyer, 1999) and a 100m buffer would be more appropriate. If a 100 m buffer is used from the middle of the seismic lines, 18,810.59 ha of all peatlands are affected, and 5982.12 ha of all BTNN and 3802.46 ha of all FTNN peatland types (Table 2.6).

Algorithm:

1) Select all **peatland polygons** (rather selecting by peatland type) that have equal to or less than 2 % disturbance **per polygon** and conserve immediately. Conservation should include protection from seismic explorations, well sites, and pipelines as well as peat extraction. The 2% cut-off was selected because a subsample of 120 peatland polygons (2% of all peatlands mapped) showed that 1/3 had less than 2% disturbance based on 1995 disturbance data. It is assumed that the amount of disturbance increased over the last five year and that the cut-off of 2% may not be appropriate any more, but that a new cut-off may have to be decided on.

2) Choose the least disturbed peatland polygons of each AWI type and conserve according to the conservation measures based on relative peatland type abundance.

Research history

Research history can sometimes be used to make decisions in regards to conservation evaluations. A peatland in which research took place may be considered more valuable simply by the fact that we have some knowledge about it.. Ideally the research value should be assessed on individual peatland basis. This can be accomplished by having research information stored at the S.C. Zoltai Peatland Information Centre and the Prairie and Northern Plant Diversity Centre, both at the Devonian Botanic Garden, University of Alberta. Research sites can be readily identified in a GIS data base and linked to peatland data sets.

Algorithm:

1) Select all sites that have been studied in the past and for which we have data available.

2) Select sites with the most ecological integrity (least disturbance) unless sites are selected for disturbance studies.

3) Conserve according to the conservation measures based on relative peatland type abundance and other parameters suggested in this study.

Future Research

Peatland polygons that have been identified as having research history are good candidates for future research because a data base is already established as pointed out above.

Algorithm:

1) Select all sites that have a research history and for which data are available.

2) Select sites with the most ecological integrity (unless for disturbance study).

3) Conserve according to the conservation measures based on relative peatland type

PEATLAND CONSERVATION RANKING ON THE LANDSCAPE LEVEL

Introduction

Data and conservation considerations from the above criteria have been summarized in a 2 x 2 table to assess overall conservation measures on the landscape scale of the GIS AWI data base. It must be remembered that the above algorithms serve as a tool for future management purposes at a finer level and with an expanded, and hopefully interactive (see ALCES in recommendations section) data base that contains more species data (e.g. caribou site data), updated linear disturbance data, and research data. The 2 x 2 table is used to give an overall rating of the AWI peatland types in respect to conservation, but perhaps more importantly in respect to peatland type abundance, degree of anthropogenic disturbance, and where available peatland plant data. All criteria used are important but the list is not complete; other criteria such as carbon sequestering (and already stored), maintenance of water quality and flow, and climate control should be considered. The latter criteria were not used because of lack of available and/or suitable data.

Methods

Table 2.9 results section, lists the following criteria: percent of total peatland area, percent of total peatland polygons, caribou habitat, plant diversity, plant rarity, and percent of disturbed surface area. Research history criteria were omitted because only the sites from this study were readily available in a GIS format. Ratings for rarity were discussed in Management Recommendations & Discussion. Peatlands were ranked by their abundance based on number of polygons and surface area. Conservation Values (CV) of 1, 2, and 3 were given for common, intermediate, and rare peatland types respectively. Peatland types that provide caribou habitat received a CV of 3 because caribou is a threatened species in Alberta. Peatlands that are treed or forested bogs or fens (BT and FT) were identified as caribou habitat based on the latest caribou habitat study by Anderson (1999). Forested peatland types (BF) were included in the treed

peatland types in Anderson's study. Peatlands that are not known to provide habitats to rare, threatened, or endangered fauna received a CV of 1.

Plant diversity was ranked by plant species diversity means per peatland type: no rare plants, CV = 1; < / = to 25 species, CV = 2; > 25 species, CV = 3. Plant rarity was ranked by the number of species occurring per peatland type: no rare plant species, CV = 1; one rare plant species, CV = 2; 3 or more rare plant species, CV = 3.

Disturbance cut-offs were based on the most obvious visual cuts (Fig. 2.7). Although there are not always big gaps to suggest a natural break (as expected in anthropogenic data), the break between BTNR and FOPI appears to be a reasonable point. The difference between high disturbance and intermediate disturbance (between BTXC and FTNN) seems more obvious.

The CV values per criterion were used as multipliers to calculate high and low conservation ratings per peatland type. If the CV values per criterion are added the numerical span is small (8-15) and the values do not seem to separate the peatland types ecologically. If CV values per criterion are used as multiplier, the numerical span becomes larger (6 to 243) and the peatland types are separated more distinctly. Although a value of 1 can represent a significant difference (e.g. pH), intuitively we respond more favourably to larger number differences and it is for this reason that the CV per criterion were multiplied to obtain a final value.

The number of polygons actually sampled (inventoried) in this study represents only 1.65 % of all peatland polygons mapped. With such a small sample, extrapolations may be drawn, but one must remember that the actual number of rare species may be higher, and that other peatland types may provide rare species habitat. It is for this reason that at least a CV of 1 was allocated for the peatland types with no rare species.

Results and discussion of conservation values

Of the 15 peatland types mapped and assessed on the landscape level the conservation ratings ranged from CV 6 to CV 243 (highest conservation value) (Table

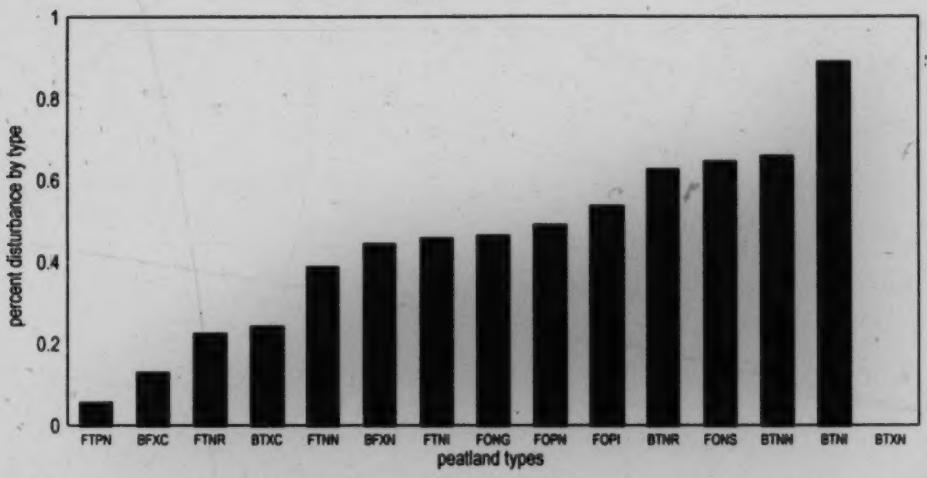

Figure 2.7. Percent peatland disturbance by peatland type based on 15 m seismic width. Peatland type BTXN had no disturbance at the time of data analysis.

2.9). Overall, peatland type FTPN shows the highest conservation value of 243. Species diversity and rarity are high as expected in patterned peatlands. Patterning is associated with higher habitat heterogeneity (discussed below) that provides more habitat types or ecological niches.

Based on the criteria chosen (often because of data availability and suitability) BTNN peatlands have the lowest conservation value. However, one must remember that BTNN peatlands fulfill other important ecological functions such as controlling run-off, maintaining water quality, and sequestering and storing huge amounts of carbon. In western Canada (Manitoba, Saskatchewan, and Alberta), peatlands store 41.8 Pg of carbon as living ground layer (Vitt et al., 2000) and are important factors in the global carbon budget. As more carbon data become available in relation to AWI peatland types, carbon storage and sequestering can be assessed on the landscape level using the GIS peatland inventory.

The role of peatlands in maintaining water quality is difficult to assess because ground water hydrology is not currently mapped.

While diversity or possible plant rarity is not expected to be extreme in bogs, bryophyte diversity in bogs associated with thermokarst activity may be higher. Similarly, diversity and rarity may be higher in patterned fen types compared to non-patterned fen types. This assumption may be made because patterned fens (FTPN and FOPN) and bogs with collapse scars or internal lawns provide more microhabitats heterogeneity compared to non-patterned peatlands or non-thermokarst bogs. Bryophyte species diversity and rarity are generally determined by the number and types of microhabitats and the most important autogenic factors governing bryophyte distribution are shade and dryness (Vitt & Belland, 1997; Belland & Vitt, 1995). Belland and Vitt (1995) argue that thermokarst collapse allows for subsequent vegetation patterning from wet to dry, associated with light and shade, depending on the development of the peatland. Based on Belland and Vitt (1995), peatlands associated with thermokarst collapse should probably receive a higher conservation value than given in Table 2.9 because of the potential for higher diversity and rarity.

Table 2.9. Peatland conservation assessment on the landscape level. CV = conservation ratings: 1 = low value, 2 = intermediate, and 3 = high conservation value. R=rare, I=intermediate, C=common; Plant diversity and rarity data was not available for all peatland types; * are plots that don't have plant diversity and rarity data; ** not mean, but data from one plot only; *** conservation rating with plant diversity from one plot. Caribou habitat was based on work by Anderson (1999) who identified treed bogs and fens as habitat.

peatland type	% of surface area	% of number of polygons	peatland rarity	CV	preferred Caribou habitat	CV	plant species diversity	CV	plant species rarity	CV	disturbed area in %	CV	Total CV
BTNN	27.420	36.722	C	1	y	3	21.2	2	n	1	0.659	1	6
FOPI	0.058	0.033	R	3		1	n	1	n	1	0.536	2	6*
BTNI	14.322	5.213	I	2	y	3	20.3	2	n	1	0.889	1	12
FONS	8.795	19.578	I	2		1	26.9	3	3 spp	3	0.645	1	18
BFXN	0.028	0.180	R	3	y	3	n	1	n	1	0.443	2	18*
FONG	0.472	2.909	R	3		1	21	2	1 sp	2	0.464	2	24
BFXC	0.206	0.866	R	3	y	3	n	1	n	1	0.129	3	27*
BTXC	0.150	0.588	R	3	y	3	n	1	n	1	0.242	3	27*
BTXN	0.019	0.049	R	3	y	3	n	1	n	1	0.000	3	27*
FTNI	9.311	4.004	I	2	y	3	28	3	n	1	0.458	2	36
FTNN	29.656	23.125	C	1	y	3	27.9	3	1 sp	2	0.387	2	36
BTNR	5.248	3.089	I	2	y	3	21.8	2	2 spp	3	0.626	1	36
FTNR	3.352	1.961	R	3	y	3	27***	2	1 sp	2	0.225	3	54(108**)*
FOPN	0.372	0.915	R	3		1	36.6	3	3 spp	3	0.490	2	54
FTPN	0.590	0.768	R	3	y	3	27	3	3 spp	3	0.056	3	243

Since we know that microhabitat heterogeneity (the number and types of microhabitats) is a basis for diversity and rarity, peatland type FOPI should probably receive a higher ranking as well. Not only does the patterning provide a higher habitat heterogeneity, but also the internal lawns. It is expected that the CV of FOPI should be between 24 and 54, based on a hypothetical diversity and rarity rating of CV 2 and CV 3, respectively. Patterning itself provides a gradient from wet to dry in addition to a gradient from open to shade. Both gradients are the most important allogenic factors influencing bryophyte distribution (Belland and Vitt, 1995).

Although not explicitly shown for vascular plants in peatlands, it may be expected that the same allogenic factors influence vascular plant distribution, and hence, diversity and rarity.

From a species diversity and rarity perspective, patterned peatlands in continental western Canada are very important because of the habitat they provide. Rare species or species diversity is directly linked to habitat availability. Patterned peatland types in Alberta are rare and should be protected from all development, including seismic activities.

Peatland type FTNR, CV 54 (or possibly CV 108), should also receive a higher conservation considerations, including protection from seismic activity. Peatland type FTNR, similar to FTPN, has a high potential for habitat heterogeneity because remnants of permafrost (R) provide a dryer and shaded habitat compared to the fen portion of the peatland type.

Peatland types that received a lower conservation rating (=/< CV 36) should be assessed on ground before assuming that they are less valuable ecologically. While it is true that we aim at conserving species diversity and rarity, a peatland with relatively low species diversity, such as a bog, should not be automatically considered open for development. BTNN peatland types received a ranking of 6, the lowest of all peatland types. The ranking is relatively low because bogs are common within the study area, however, it must be remembered that the Phase II area was chose because it had a high density of bogs. BTNN are caribou habitats and have a high conservation value in this

respect, but low conservation rankings for diversity (2), rarity (1), and percent disturbance (1). Resource managers should consider all criteria before making a blanket decision for all BTNN peatland types and should consider bog development on individual BTNN polygons and ground assessment. The same considerations need to be applied to all peatland types.

The conservation assessment on the landscape level provides a good overview for management orientation, especially in relation to peatland type rarity. Patterned fens, especially FTPN and FOPN, are certainly worthy of conservation based on most criteria. The assessment also identifies where research is needed to improve our approach to peatland management in Alberta. Peatland type FOPI was not ranked high under the criteria but it must be remembered that plant species data were not available for the two FOPI polygons. Because the peatland type is mapped, plant diversity and rarity data may be obtained in the future and the assessment can be easily updated. Species data may also be obtained for other peatland types for which data were not available. Other criteria may be added as data such as carbon stored by peatland type become available.

In summary, the peatland management key provides a tool for managing individual peatlands while the landscape assessment provides a reconnaissance type overview of all peatland types within a relatively large and inaccessible study area.

PROPOSED ACTIONS

Although it is admirable that the provincial government is taking action to develop a peatland management policy, I recommend that an integrated and holistic approach in addition to the initial peatland conservation assessments. The Boreal Forest should be managed as one ecosystem and not in small isolated sections dissected by resource industry (e.g forestry, horticultural peat mining, oil and gas). It does not make sense to evaluate peatlands separately from forested lands or aquatic systems as they all function together and are often hydrologically connected.

In order to create meaningful representation of the Boreal Forest landscape,

reserve sets including all ecological units (forests, all wetlands, and aquatic systems) should be selected. Cumulative affects should be assessed for the entire landscape; i.e. all anthropogenic influences on all ecosystems. Perhaps this sounds like a daunting task but if models like ALCES (Alberta Landscape Cumulative Effects Simulator, Forem Consulting) are applied, cumulative effects can be assessed on the landscape level.

To be able to manage the Boreal Forest on the landscape level, all associated industry and other interest groups have to co-operate. A round table approach involving industry, government, researchers, and conservation associations may be the basis for it.

A) Relative Peatland Type abundance within Phase II study area

The relative peatland type abundance will not change unless peat harvesting begins to take place within the study area. If peatlands are harvested (or drained for other purposes such as forestry) the affected peatland polygons should be identified in the AWI GIS data base. Once identified as harvested or drained, peatland type abundance and conservation considerations must be re-assessed to make sound (sustainable) management plans.

It is suggested to keep an active data base with an interactive model to evaluate present and proposed disturbances to ensure good conservation measures.

B) Species Diversity

Species diversity should be monitored as new data become available. This can be achieved by asking researchers, consultants, and government agencies to contribute their data to the S.C. Zoltai Peatland Information Centre at the Devonian Botanic Garden and/or the Prairie and Northern Plant Diversity Centre. See point E, research.

C) Rare, threatened, or endangered species

As above, new rare, threatened, or endangered species data should become part of an active data base for monitoring and resource management. Plant data ideally is shared with ANHIC, vertebrates data with the Alberta Wildlife Management Division, caribou data with the Boreal Caribou Research Program, invertebrate data with the Provincial Museum.

As above, it is suggested to keep an active data base with an interactive model for resource management purposes.

D) Anthropogenic disturbance

Most anthropogenic disturbance in peatlands is caused by the hydrocarbon industry in the form of seismic lines, well sites, and pipelines. The PMTF should approach the AEUB and industry to cooperate in peatland management by a) honouring peatland conservation goals, by b) maintaining an up-to-date disturbance layer, and by c) paying a fixed contribution per kilometer for seismic line reclamation.

The disturbance layer could be used to monitor rate of disturbance by peatland types and surface area. A similar model like ALCES could be applied here.

Horticultural peat harvesting should take place on sites that are already disturbed by other industrial activities compared to sites that have little disturbance.

E) Research history

Past research data should be linked to the GIS data base by geographical location. These data could be used to expand our understanding of rare species sites, high diversity sites, permafrost features, caribou sites, or other parameters.

Future research can also be tied into the AWI data base, especially by either selecting research sites from the data base or linking research to the data base by UTM references.

For most of the above suggestions it is essential that a person that has excellent working knowledge in ArcInfo and ArcView is employed to complete the tasks. Perhaps a second person should be employed for creating an interactive interface (and model) for peatland conservation monitoring.

I suggest to invite Brad Stelfox, Forem Consultants, to demonstrate the ALCES model to the PMTF. A demonstration would explain the applicability and usefulness of such models, as well as the above points.

Other possible applications for a peatland GIS layer are the analysis of number and size of peatland complexes; i.e. how many peatland types are connected by

hydrology. For example, a peatland complex may be composed of an open, shrubby fen that grades into a tree fen, and within the fens may be some treed bog islands. Thus, the complex is composed of three peatland types. Hydrological connections in peatlands can often be identified on aerial photographs. A peatland complex has more different habitats that only one peatland type and may be important in biodiversity assessments, in selecting research sites, in selecting sites for conservation (often it is desirable to select sites that conserve the most number of species), or in watershed management.

GIS data bases, depending on the accuracy of the mapping, can be overlaid with other data bases for a large number of spacial analyses. A very useful application may be the overlay of the Alberta Vegetation Inventory (AVI) to assess factors from run-off from timber harvesting to fire modeling. Another very useful application in land resource management is the use of mapped disturbances. In the Boreal Forest of Alberta linear disturbances are of concern in conservation and management and GIS analysis is an excellent tool for such assessment.

GIS data bases are also very useful in assessing wildlife land use. Radio telemetry data can be used in spacial analysis to assess which land type (e.g. treed bogs, old jack pine stands) is generally used during a certain season by a species. Examples in boreal Alberta are the use of radio telemetry data in caribou research (Anderson, 1999; Dyer, 1999).

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CHAPTER III: DOES SCALE MATTER?
Landscape Scale Classification and Ecological Site Evaluation in Boreal Peatland Resource Management in Alberta

INTRODUCTION

Alberta's peatland management key (see Chapter 2) provides a means to manage peatlands on the landscape level and addresses several management criteria to provide a means to balance conservation and development. However, little information is given in respect to on-ground site assessment and how floristic site specificity is linked to landscape scale inventories.

Alberta Wetland Inventory (AWI) Standards (Halsey & Vitt, 1996) were developed to classify and inventory peatlands at the landscape level. While peatland resources can be inventoried using AWI standards, peatland managers need more information for on-site evaluations, especially when assessing rare plant species habitat or species richness at the local scale.

In Alberta we have a good knowledge base of peatland ecology, types, distribution, abundance, and bryophyte species richness and rarity (Vitt & Belland, 1997; Belland & Vitt, 1995; Vitt et.al, 1995; Zoltai and Vitt, 1995; Halsey et.al, 1995; Vitt, 1994; Vitt et.al, 1994; Zoltai, 1993; Vitt, 1992; Chee and Vitt 1989), and while floristic differences of peatlands have been shown in the past (Belland & Vitt, 1995; Vitt et al., 1995; Chee & Vitt, 1989), no attempt was ever made to develop an ecological wetland classification system for management purposes at the local scale, or to merge peatland management from landscape to local scale.

At the landscape level, AWI standards allow identification of peatlands by hydrological units (fen, bog), landform features (presence of permafrost, signs of permafrost decline, or patterning), and vegetation modifiers (treed, forested, shrub or graminoid dominated). While the above features are identifiable on aerial photographs, site specificity of peatlands based on floristics are not.

While the AWI is an excellent tool for landscape scale type assessment in natural resource management, it has never been shown how site specificity or floristic groups are related to landscape scale mapping and inventory. Because of the two different scales; i.e. small scale on the landscape level (latest inventory at 1:50,000) to large scale at site, peatlands on-ground may not match AWI classification.

Linking of landscape scale AWI classification with on-ground assessment is necessary in a large and inaccessible landscape to make ecologically sound management decisions and to manage peatlands with a higher degree of confidence in boreal Alberta.

In this chapter, the following factors are addressed to provide more detailed information to land resource managers: a) Do AWI peatland types differ from on-ground, site specific peatland types because of difference of scale; b) if peatland types are classified differently at different scales, how are AWI peatland types placed in on-site peatland types; and c) which local peatland types are expected to have high species richness and/or rarity?

Ecological overview of peatlands in Western Continental Canada

Continental boreal peatlands include geogenous fens and ombrogenous bogs. Fens receive mineral-enriched groundwater while bogs are raised above the water table level and receive water from precipitation only, thus separating the two peatland types on hydrological basis. Important factors in peatland development and classification are hydrology, chemistry, and biotic factors. A combination of these factors results in the development of a ground layer dominated by *Sphagnum* or brown mosses (Zoltai & Vitt, 1995).

Alberta's fens can be divided into poor, moderate-rich, and extreme-rich fens based on their surface water pH, cations, conductivity and associated vegetation (Chee & Vitt, 1989; Vitt & Chee, 1990; Vitt et al., 1995). They can be dominated by sedges, grasses, shrubs or *Sphagnum,* representing a chemical and moisture gradient (Vitt & Chee, 1990). Only two tree species are normally associated with Alberta's peatlands: *Larix laricina* and *Picea mariana;* the latter generally is the only tree species in bogs.

Generally, bogs are acidic (pH < 4) and dominated by oligotrophic *Sphagnum* species (Vitt, 1994). Poor fens (pH 4.0-5.5) are dominated by mesotrophic *Sphagnum* species while moderate-rich fens (pH 5.5-7.0) and extreme-rich fens (pH >7.0) are characterized by brown mosses (Vitt, 1994). Moderate-rich fens can also have mesotrophic species of *Sphagnum* such as *S. subsecundum* or *S. teres*.

Few fens are found within the pH range of 5.1-5.6 (Vitt, 1994). In this range alkalinity drops to zero and the peatland becomes a *Sphagnum*-dominated peatland (Vitt, 1994). This transition is rapid (100-200 years) because *Sphagnum* can acidify its environment, thus causing oligotrophication (Kuhry et al., 1993; Vitt et al., 1994). The rather narrow temporal window causes these fens to be rare.

South of the continuous permafrost zone, peatlands can be underlain by permafrost. Permafrost-dominated peatlands (including peat plateaus) are raised above the water table and drier conditions allow for dense, tall conifer growth in the south, and open-canopy, *Cladina*- dominated plateaus in the north (Vitt et al., 1994).

Permafrost-underlain peatlands can be subject to thawing and two landform features are common in continental western Canada: collapse scars and internal lawns (Zoltai, 1971; Vitt et al., 1994). It is important to note that collapse scars form treeless circles (leaning trees at the margins are common) within the matrix of permafrost underlain peatlands, compared to internal lawns that are described next.

Internal lawns are generally dominated by "wet" species of *Sphagnum* and *Carex* (Vitt et al., 1994) but later successional stages may be dominated by ombrotrophic *Sphagnum* and *Eriophorum* (pers. observation). Partially buried, leaning trees, dead or alive, are often present (Vitt et al., 1994). Internal lawns are remnants of permafrost collapse, but they are not surrounded by permafrost.

Bryophytes are important indicators of water chemistry (pH, alkalinity, cation exchange capacity, conductivity) and moisture levels, while vascular plants are important indicators of nutrients, especially nitrogen and phosphorus (Vitt & Chee, 1990). Hence, bryophytes are excellent indicators of change and peatland condition. Bryophyte diversity in peatlands is largely determined by habitat heterogeneity (Belland

& Vitt, 1995; Vitt et al., 1995), generally following chemical and moisture gradients. Bryophyte fidelity and species richness in peatlands has been discussed in detail by Vitt & Belland (1997), Vitt et al. (1995), Belland & Vitt (1995), and Vitt & Chee (1990). Generally, in the above studies peatlands were grouped into one to all of the five major types as follows: continental bog, peat plateau (permafrost underlain) or other permafrost related feature such as collapse scar or internal lawn, poor fen, moderate-rich fen, or extreme-rich fen. From these studies we know that bryophyte diversity is closely linked to habitat heterogeneity (number of microhabitats) (Vitt et al., 1995), that bryophyte distribution is affected by shade, dryness (Belland & Vitt, 1995), alkalinity and acidity (Vitt & Chee, 1990), and that vascular plant distribution is affected by a nutrient gradient, especially N and P (Vitt & Chee, 1990).

Habitat heterogeneity in peatlands can be attributed to several peatland and landform features. Permafrost collapse and subsequent successional changes generate a gradient of habitats. Initially, collapse scars and internal lawns are rather wet but become drier as succession proceeds. Simultaneously, light conditions change when the usually tall, dense conifers on peat plateaus tilt with subsidence. In the early, very wet successional stages internal lawns are exposed but conifers will establish themselves again in the late successional stages, thus providing shade as succession proceeds after thermokarst decline. A gradient of wet to dry may develop simultaneously. Hence, peatlands that have or had permafrost have a higher potential for number of habitats compared to homogeneous fens or continental bogs, although successional stages may determine the numbers of microhabitats and the degree of variation.

Patterned fens have the potential to have more microhabitats because of the wet to dry gradient generated by strings and flarks, and the associated vegetational differences that can affect canopy closure. Other microhabitats are hummocks, hummock sides, lawns, carpets, pools, tree bases, shaded tree base depressions, humidified peat, and forest duff (Vitt et al., 1995).

If biodiversity is a critical factor in site selection for conservation, Vitt et al. (1995) recommended that models should be based on peatland type, habitat

heterogeneity and pH. Peatland types at the site level are defined by their flora that is linked to a combination of habitats and water chemistry. The flora can be a combination of dominant vegetation and indicator species that are not necessarily present in great abundance.

METHODS

A study area of 12,556 km^2 (Fig. 3.1) was chosen based on peatland density obtained from the Alberta peatland inventory summary map at 1:1,000,000 scale (Vitt, 1992). The map indicates a high concentration of peatlands within northeastern and north-central Alberta's Aspen Parkland and Boreal Forest. Peatlands were inventoried to AWI standards and mapped at the 1:50,000 scale and printed by the Alberta provincial government (Forest et al., 2000).

Sample locations (plots) were chosen with the objective to obtain representative samples from within the entire study area. Samples locations within a given peatland were selected away from cutlines, although not only peatlands without disturbance were selected. Distance from a cutline to the actual plot was not recorded. Areas surveyed had to be visually homogeneous and could not grade from one peatland type into another. Such decisions were made in each plot based on personal wetland working experience of > 300 plots for ecological landscape classification. An effort was made to obtain multiple samples for each peatland type as identified under the AWI Standards, although the study area was not mapped until after field sampling. Hence, sites were selected by a combination of geographic distribution and trying to anticipate AWI peatland types (see Fig. 3.1 for site locations). Between June and the end of August, 1996, 135 plots were sampled in the study area that was later inventoried to have 6,119 peatland polygons (Forest et al., 2000). Plots with at least 40 cm of peat were defined as peatlands based on the Canadian Wetland Classification System in Wetlands of Canada (National Wetlands Working Group, 1988), but in most cases peat depth was greater.

A spatially unbounded-plot approach was taken to inventory flora. An unbounded plot eliminated the need of finding a truly representative spot of a given

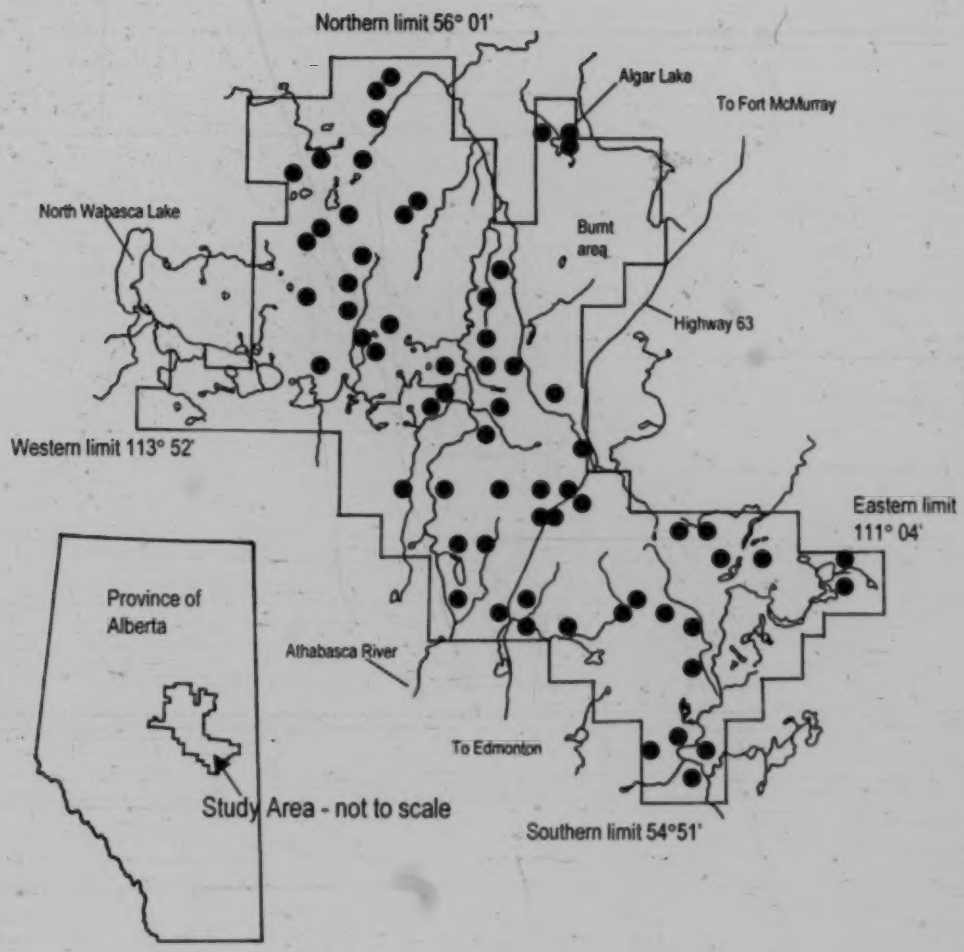

Fig. 3.1. Study area (12,556 km²) in northeastern Alberta, Canada. Dots represent study locations; one dot may represent more than one site.

size, typically a 5 x 5m or 10 x 10 m quadrat for floristic inventory. It allowed for expansion of the area surveyed until no more new species were found. The actual area surveyed was not measured. Abundance by species was recorded in the following way: 3 = species is abundant throughout (dominant); 2 = species occur scattered throughout in clusters e.g. confined to hummocks; 1 = species occur only scattered and infrequent; "+" = species only occur as a trace (adapted from Vitt et al., 1990). Woody species were recorded by species in addition to height. Four height categories were recognized: 1 = tress . 10 m tall; 2 = trees/shrubs 2 - 10 m tall; 3 = trees/shrubs 0.5 - 2 m tall; and 4 = trees/shrubs < 0.5 m tall. All vascular plant species, bryophytes, and lichens were recorded, except epiphytes.

Species nomenclature follows Moss (1994) for vascular plants, except for *Vaccinium oxycoccos* that follows Soper and Heimburger (1990); Crum (1984) for *Sphagnum*; Schuster (1966) for hepatics; Egan (1987) for lichens other than *Peltigera;* Goffinet and Hastings(1994) for *Peltigera;* and Anderson et al. (1990) for Bryidae with the following exceptions: nomenclature follows Koponen (1974) for Mniaceae, Shaw (1982) for *Pohlia*, and Janssens (1983) for *Drepanocladus*. Throughout the text genus and species are given in most cases rather than using the convention of abbreviating the genus name after it appeared once.

Plot locations were linked to mapped AWI peatland polygons by entering plot locations in the GIS data base by UTM references. Not all of the plots could be linked because some plots were located in peatlands that were smaller than 0.5 ha; thus, although 135 plots were surveyed only 98 plots could be linked. The smallest mappable polygon used at the 1:50,000 scale was 0.5 ha; thus some plots are not identified in the GIS data base. Because some on-ground plots were eliminated, some AWI classes were eliminated, too. Overall, 98 plots, seven TWINSPAN groups (2, 4, 5, 6, 7, 9, 10) and ten AWI peatland types were used to test congruency of the two peatland management scales. To test congruency, the number and types of AWI classes per TWINSPAN group were calculated in percent.

TWINSPAN (Hill, 1979, modified by Minchin, 1997) was used to classify the

plots. Species were entered using the first three letters of the genus, followed by the first three letters of the species, and if a woody species the height. The tree species *Picea mariana* at a height bracket of 2 - 10 m would have been entered as PICMAR2.

Pseudospecies cut levels used were 0.00, 0.50, 1.50, and 2.50 because of the abundance scale of + (entered as 0.01), 1, 2, and 3. Preferential species defined by TWINSPAN were used to describe floristic groups.

For each TWINSPAN group the mean and standard deviation of the number of species (species richness) were calculated.

Depth to mineral soil or active permafrost (active layer depth) was determined by pushing a steel rod (appr. 1.5 cm in diameter) through the peat until the resistance of mineral soil (and scraping sound) became evident. Presence of permafrost was ascertained by a sudden stop and dull 'thud' of the steel impacting on ice. Presence of permafrost (compared to seasonal frost) was further determined by comparing surface vegetation and topography with description by Zoltai (1993), Vitt et al. (1994), and Halsey et al. (1995).

National and provincial plant species rarity was assessed by comparing the plant species inventoried to Gould (1999), the Alberta Natural Heritage Information (ANHIC) tracking list.

Local species rarity and richness were further assessed by the number of occurrences in the study. Local species rarity was assessed by calculating the percent of species that occurred only once and twice, respectively. All species, even species that appeared to be accidentals in peatlands such as *Trifolium pratense,* were included to avoid arbitrary or perhaps subjective selection of species. TWINSPAN peatland types that provided rare species habitat, local rarity and ANHIC rarity, were identified. The number of rare species per TWINSPAN peatland type, as well as the percentage of the locally rare species, were calculated.

RESULTS AND DISCUSSION

TWINSPAN Groups

The 135 plots have been hierarchically classified into groups by TWINSPAN. The 278 species, that include layers of woody species, were arranged in groups. Based on this classification, twelve plot and species groups (TWINSPAN groups) were recognized as forming meaningful clusters. Eigenvalues and indicator species for each dichotomy of the plot group dendrogram are given in Figure 3.2. An overview of the characteristics of each TWINSPAN group and species abundance averages by species group (Table 3.1) are given below.

TWINSPAN group 1 (n=2) is differentiated by the high abundance averages of *Sphagnum angustifolium, Alnus rugosa* (2 - 10m tall), *Rubus acaulis, Salix planifolia* (2 - 10 m tall), and *Calamagrostis canadensis*. *Betula papyrifera* (2 - 10m tall) and *P. mariana* (from > 10 m tall to < 0.5 m tall) are also present but at lower average abundances. Species that are limited to group 1, although at lower average abundance values, are *Cornus canadensis, Abies balsamea, Lycopodium annotinum, Plagiothecium denticulatum, Pseudobryum cinclidioides, Ribes glandulosa, Salix discolor, Eurhynchium pulchellum, Geocalyx graveolens, Picea glauca,* and *Viburnum trilobum.*

Group 1, although with a mean peat depth of 252.5 cm, is more similar to a poor (poor in nutrients and species) conifer swamp than to a peatland. Conifer swamps are generally more nutrient and often more species rich than peatlands (National Wetlands Working Group, 1988; Racey et al., 1996; Harris et al., 1996). Typically the peat-forming bryophyte species in group 1 were *Sphagnum angustifolium, S. russowii, S. teres* and *S.squarrosum*. While *S.angustifolium* is found in many peatland types, the other three species are typically found in wetter conditions (Crum, 1992). Species other than those typically found in peatlands were *Alnus rugosa* and *Calla palustre*. Both species generally occur in nutrient richer or wetter sites (Harris et al., 1996). Species that are typically associated with mineral soil were *Betula papyrifera* and *Pyrola virens*. Group 1 has the highest species mean of 46 species (Fig. 3.3).

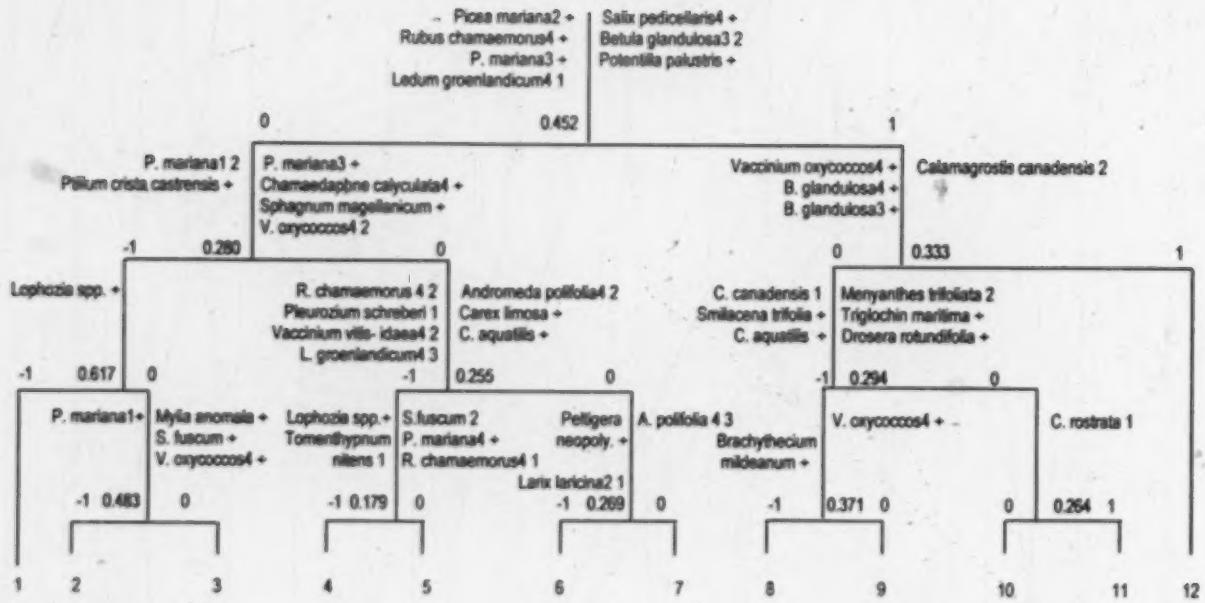

Fig. 3.2. Dendrogram for TWINSPAN output, groups 1 to 12. Numbers of 0, 1 and -1 give the maximum and minimum indicator scores for negative and positive groups respectively. Negative groups are listed on the left-hand side of the division line. Other numbers at the divisions are the respective eigenvalues. Height layers for woody species are given directly after the species name, followed by an abundance value. Height layers are: 1=trees > 10m, 2=trees/shrubs 2-10m, 3=trees/shrubs 0.5-2m, and 4=trees/shrubs <0.5m tall. *Peltigera neopolydactyla* has been abbreviated to *P. neopoly*.

Table 3.1. Species abundance average values on a scale of 0 - 3 (see methods) for TWINSPAN groups 1 to 12. Values less than 0.5 are represented as +. Height layers for woody vegetation : 1=trees > 10m, 2=trees/shrubs 2-10m, 3=trees/shrubs 0.5-2m, and 4=trees/shrubs <0.5m. Locally rare species are identified by their occurrence of one or two.

Species	height	occurrences 1	occurrences 2	TWINSPAN Groups 1	2	3	4	5	6	7	8	9	10	11	12
			n =	2	5	2	3	44	8	27	4	16	20	2	2
Picea mariana	1			2	3	1	+	+	–	–	–	+	–	–	–
Cornus canadensis				+	–	–	–	–	+	–	–	–	–	–	+
Dicranum fragilifolium				+	+	–	–	+	+	–	–	–	–	–	–
Abies balsamea	2		2	+	–	–	–	–	–	–	–	–	–	–	–
Abies balsamea	3		2	+	–	–	–	–	–	–	–	–	–	–	–
Lycopodium annotinum		1		+	–	–	–	–	–	–	–	–	–	–	–
Plagiothecium denticulatum		1		+	–	–	–	–	–	–	–	–	–	–	–
Pseudobryum cinclidioides			2	2	–	–	–	–	–	–	–	–	–	–	–
Ribes glandulosum	4	1		+	–	–	–	–	–	–	–	–	–	–	–
Salix discolor	2			1	–	–	–	–	–	–	–	–	–	–	–
Rubus pubescens	3			–	+	–	–	–	–	–	–	–	–	–	–
Eurhynchium pulchellum		1		+	–	–	–	–	–	–	–	–	–	–	–
Geocalyx graveolens		1		+	–	–	–	–	–	–	–	–	–	–	–
Picea glauca	1	1		1	–	–	–	–	–	–	–	–	–	–	–
Viburnum trilobum	4	1		+	–	–	–	–	–	–	–	–	–	–	–
Cephaloziella byssacea				–	+	–	–	+	–	+	–	–	–	–	–
Cladina mitis				+	+	3	+	1	+	+	–	+	+	–	–

Dicranum polysetum			–	+	+	+	+	+	+	–	–	+	–	–
Ledum groenlandicum	4		+	1	3	2	3	2	+	+	+	+	–	+
Ledum groenlandicum	3		–	–	+	–	+	–	–	–	–	–	–	–
Pleurozium schreberi			+	3	2	1	1	+	+	–	+	+	–	1
Sphagnum russowii			1	+	+	+	+	+	+	–	+	–	–	–
Vaccinium vitis-idaea	4		1	1	3	3	2	1	+	–	+	+	–	+
Icmadophila ericetorum			–	+	+	–	+	–	–	–	–	–	–	–
Cladina stellaris			–	–	+	–	+	+	–	–	–	–	–	–
Dicranum fuscescens			+	–	–	–	+	–	–	–	–	–	–	–
Picea mariana	4		1	+	+	+	2	1	1	+	+	+	–	+
Picea mariana	2		1	+	1	2	2	2	+	–	+	+	–	+
Picea mariana	3		–	–	+	2	2	3	1	–	+	+	–	+
Rubus chamaemorus	4		1	1	3	1	2	+	1	+	+	+	–	–
Cladina rangiferina			–	–	1	–	+	+	+	–	–	–	–	–
Politrichum commune		2	–	–	–	–	+	–	+	–	–	–	–	–
Cephalozia connivens			+	–	–	–	+	–	+	–	–	–	–	–
Cephalozia loitlesbergeri			–	–	–	–	+	–	+	–	–	–	–	–
Sphagnum capillifolium			–	–	1	+	+	+	+	–	+	+	–	–
Equisetum palustre		1	–	–	–	–	+	–	–	–	–	–	–	–
Peltigera scabrosa		1	–	–	–	–	+	–	–	–	–	–	–	–
Gaultheria hispidula	4		–	–	–	–	+	–	+	–	–	–	–	–
Cephaloziella spinigeria			–	–	–	+	+	–	+	–	–	–	–	–
Juncus bufonicus		1	–	–	–	+	–	–	–	–	–	–	–	–
Cetraria nivalis			–	–	–	–	+	–	–	–	–	–	–	–

Pinus banksiana	1		2	–	–	–	–	+	–	–	–	–	–	–	–
Vaccinium myrtilloides	4		2	–	–	–	–	+	–	–	–	–	–	–	–
Amblystegium serpens		1		–	–	–	–	+	–	–	–	–	–	–	–
Maianthemum canadense		1		–	–	–	–	+	–	–	–	–	–	–	–
Empetrum nigrum	4	1		–	–	–	–	+	–	–	–	–	–	–	–
Dicranum scoparium				–	–	–	–	+	–	–	–	–	–	–	–
Sphagnum lindbergii		1		–	–	–	–	+	–	–	–	–	–	–	–
Plagiomnium medium				–	–	–	–	+	–	–	–	–	–	–	–
Salix pedicellaris	3	1		–	–	–	–	+	–	–	–	–	–	–	–
Pinus banksiana	2		2	–	–	–	–	+	–	–	–	–	–	–	–
Equisetum arvense			2	–	–	–	+	–	+	–	–	–	–	–	–
Anastrophyllum minutum		1		–	–	–	–	–	+	–	–	–	–	–	–
Ranunculus lapponicus		1		–	–	–	–	–	+	–	–	–	–	–	–
Pedicularis groenlandica		1		–	–	–	–	–	+	–	–	–	–	–	–
Cephalozia hampeana		1		–	–	–	–	–	+	–	–	–	–	–	–
Myurella julacea		1		–	–	–	–	–	+	–	–	–	–	–	–
Cladopodiella fluitans				–	–	–	–	+	–	+	–	–	+	–	–
Carex pauciflora				–	–	–	–	+	–	+	–	–	–	–	–
Sphagnum majus			2	–	–	–	–	–	–	+	–	–	–	–	–
Myrica gale	4		2	–	–	–	–	–	+	+	–	–	–	–	–
Epilobium ciliatum		1		–	–	–	–	–	–	+	–	–	–	–	–
Spirodela polyrhiza		1		–	–	–	–	–	–	+	–	–	–	–	–
Ledum palustre	4	1		–	–	–	–	–	–	+	–	–	–	–	–
Scorpidium scorpioides		1		–	–	–	–	–	–	+	–	–	–	–	–

Polytrichum juniperinum		2	+	–	–	–	–	–	+	–	–	–	–	–
Eriophorum vaginatum			–	–	+	+	+	+	1	–	+	+	+	–
Pohlia sphagnicola			–	–	+	+	+	+	+	–	+	+	–	–
Sphagnum magellanicum			–	+	–	+	1	1	2	–	+	+	–	–
Chamaedaphne calyculata	4		–	–	–	–	1	+	1	+	+	+	–	–
Kalmia polifolia	4		–	–	–	–	+	–	+	–	+	–	–	–
Cephalozia lunulifolia			–	–	–	–	+	–	+	–	+	–	–	–
Eriophorum brachyantherum			–	–	–	–	+	–	+	–	–	+	–	–
Cladonia species			+	+	+	+	+	+	+	+	+	+	–	+
Mylia anomala			+	–	+	+	+	+	+	–	+	+	–	+
Sphagnum fuscum			–	–	2	1	2	+	1	–	+	+	–	–
Polytrichum strictum			+	+	–	+	+	+	+	–	+	+	–	–
Peltigera neopolydactyla			–	–	–	+	+	+	–	–	+	+	–	–
Calypogeia sphagnicola			–	+	–	+	+	–	+	+	+	+	–	–
Dicranum undulatum			–	+	+	+	+	+	+	+	+	+	–	+
Lepidozia repens			+	+	–	–	+	+	–	–	–	+	–	+
Peltigera aphthosa			+	+	–	+	+	+	–	+	+	+	–	–
Blephorostoma trichophyllum			+	–	–	+	+	+	–	–	+	–	–	–
Hylocomnium splendens			+	+	+	+	+	+	+	+	–	+	–	–
Larix laricina	1		+	–	–	–	+	+	+	–	+	–	–	–
Peltigera malacea			–	+	–	–	+	–	–	+	–	–	–	–
Ptilium crista-castrensis			+	+	+	+	+	+	–	–	+	+	–	+
Ptilidium ciliare			–	+	–	+	+	–	+	+	–	+	–	–
Tetraplodon mnioides			+	+	–	–	+	–	–	+	–	–	–	–

Salix pyrifolia	3		–	–	–	–	+	–	–	–	–	–	–	1
Peltigera canina		2	–	–	–	–	+	–	–	–	+	–	–	–
Ptilidium pulcherrimum			+	+	–	–	+	–	–	–	–	+	–	–
Aneura pinguis			+	–	–	+	+	–	–	–	–	+	–	–
Tetraplodon angustatus			–	+	–	–	+	–	–	+	–	–	–	–
Carex trisperma			–	+	–	–	+	+	–	–	+	–	–	+
Betula papyrifera	2		2	+	–	–	+	–	–	–	–	–	–	+
Dryopteris carthusiana		2	+	–	–	–	–	–	–	–	–	–	–	+
Sphagnum angustifolium			3	+	1	1	2	3	1	–	2	1	1	–
Vaccinium oxycoccos	4		+	–	1	1	2	2	2	–	1	2	1	–
Pohlia nutans			1	+	+	+	+	+	+	+	+	+	–	–
Lophozia species			+	–	–	+	+	+	+	–	+	+	–	–
Carex canescens			–	+	–	+	+	+	+	+	+	–	–	–
Sphagnum riparium			–	+	–	+	+	–	+	–	+	+	1	–
Smilacena trifolia			+	+	+	+	+	2	2	+	2	+	–	1
Petasitis sagittatus			–	–	–	–	–	+	–	–	–	–	–	+
Petasitis palmatus		2	–	–	–	–	–	+	–	–	–	–	–	+
Betula papyrifera	4		1	–	–	–	–	–	+	+	+	–	–	–
Andromeda polyfolia	4		–	–	–	–	+	+	2	–	+	3	–	–
Drosera rotundifolia			–	–	–	–	+	+	+	–	+	1	+	–
Alnus rugosa	2		3	–	–	–	–	–	–	–	–	–	–	1
Sphagnum contortum		2	–	–	–	–	–	–	+	+	–	–	–	–
Scheuchzeria palustris			–	–	–	–	–	–	+	–	+	+	+	–
Carex aquatilis			+	–	–	1	+	2	1	2	3	+	1	1

Ceratodon purpureus			–	–	–	–	–	+	–	+	–	+	–	–
Salix pyrifolia	4		–	–	–	–	–	+	–	–	+	–	–	–
Betula papyrifera	3		1	–	–	+	–	–	+	–	+	–	–	–
Adoxa moschatellina		2	+	–	–	–	–	–	–	–	+	–	–	–
Drepanocladus uncinatus			+	+	–	+	+	–	+	+	+	+	–	–
Viola species			1	–	–	–	–	–	–	–	+	–	–	+
Campanula aparinoides		2	–	+	–	–	–	–	–	–	+	–	–	–
Rubus acaulis			3	–	–	+	–	+	–	–	+	–	–	1
Brachythecium salebrosum		2	–	–	–	–	+	–	–	–	–	+	–	–
Ribes hirtellum	4		+	–	–	–	+	–	–	–	–	–	–	+
Salix planifolia	2		3	–	–	–	–	–	–	+	–	–	–	1
Aulacomnium palustre			1	+	+	1	+	1	+	1	1	1	–	1
Lonicera caerulea	4		+	–	–	–	+	+	–	–	–	+	–	+
Tomenthypnum falcifolium			–	–	–	–	–	+	+	–	+	+	–	–
Salix discolor	3		–	–	–	+	–	+	–	+	–	–	–	1
Equisetum sylvaticum		2	–	–	–	+	–	–	–	–	–	–	–	+
Mitella nuda			+	–	–	–	–	+	–	+	–	–	–	+
Ribes hudsonianum	4	2	+	–	–	–	–	–	–	+	–	–	–	+
Calamagrostis canadensis			3	+	–	+	+	+	+	2	1	+	+	3
Galium labradoricum			+	–	–	–	–	–	–	+	–	–	–	+
Linnea borealis	4	2	–	+	–	–	–	–	–	–	–	–	–	+
Marchantia polymorpha			–	–	–	–	–	–	+	+	+	–	–	–
Pyrola asarifolia			–	+	–	–	–	+	–	+	+	+	–	–
Rhizomnium gracile			–	–	–	+	–	–	–	–	+	–	–	–

Pyrola clorantha		+	–	–	+	–	+	–	–	+	–	–	–
Drepanocladus exannulatus		–	–	–	–	–	–	+	+	+	–	–	–
Salix maccalliana	4	–	–	–	–	–	+	–	+	+	–	–	–
Bryum pseudotriquetrum		–	+	–	+	+	+	+	1	+	+	+	–
Brachythecium mildeanum		+	–	–	–	–	+	+	+	+	+	–	–
Calliergon stramineum		2	+	–	+	+	+	+	+	+	+	+	+
Carex disperma		+	+	–	+	+	+	–	+	+	+	–	1
Drepanocladus fluitans		–	+	–	–	+	–	+	+	+	+	2	–
Hypnum pratense		+	–	–	+	–	+	–	+	+	+	–	–
Sphagnum squarrosum		1	+	–	+	+	–	–	–	+	+	+	–
Sphagnum teres		1	–	–	+	–	–	+	–	+	+	–	–
Calla palustris		3	–	–	+	–	+	–	2	+	+	–	–
Plagiomnium cuspidatum		+	+	–	–	–	–	–	+	+	+	–	–
Carex gynocrates		–	–	–	–	–	+	–	–	+	+	–	–
Hypnum lindbergii		+	–	–	–	–	–	–	+	–	–	+	–
Betula glandulosa	4	–	–	–	1	+	2	+	1	1	2	–	–
Larix laricina	3	–	–	–	+	+	1	+	+	1	1	–	–
Larix laricina	2	–	–	+	+	+	2	+	–	1	1	–	–
Larix laricina	4	1	–	–	–	+	1	+	+	+	+	–	–
Sphagnum warnstorfii		–	–	–	1	+	+	+	+	+	+	–	1
Tomenthypnum nitens		+	–	+	1	+	1	+	+	+	1	–	–
Betula glandulosa	3	–	–	–	–	+	1	+	1	1	2	–	–
Epilobium palustre		–	+	–	+	+	+	+	–	+	+	–	–
Corallorhiza trifida		–	–	–	–	–	+	–	–	+	+	–	–

Pedicularis labradorica				–	–	–	–	+	+	+	–	+	+	–	–
Helodium blandowii				–	–	–	–	+	+	–	+	+	+	–	–
Salix planifolia	4			–	–	–	–	–	+	–	–	–	+	–	–
Eriophorum angustifolium				–	–	–	–	–	–	+	–	–	+	–	–
Spiranthes romanzoffiana				–	+	–	–	–	–	+	–	+	+	–	–
Carex limosa				–	+	–	+	+	1	1	–	1	2	–	1
Carex chordorrhiza				–	–	–	–	+	+	+	+	+	1	1	–
Equisetum fluviatile				–	+	–	–	+	+	–	1	+	+	1	–
Lemna minor			2	–	–	–	–	–	–	–	–	+	–	–	+
Climacium dendroides				+	–	–	–	–	–	–	1	–	–	–	+
Geum rivale			2	–	–	–	–	–	–	–	+	–	–	–	1
Brachythecium erythrorhizon		1		–	–	–	–	–	–	–	–	–	–	–	+
Cornus stolonifera	4	1		–	–	–	–	–	–	–	–	–	–	–	+
Epilobium angustifolium			2	–	–	–	–	–	–	–	–	–	–	–	+
Galium triflorum		1		–	–	–	–	–	–	–	–	–	–	–	+
Listeria cordata		1		–	–	–	–	–	–	–	–	–	–	–	+
Ribes oxyacanthoides	4	1		–	–	–	–	–	–	–	–	–	–	–	+
Rosa acicularis	4		2	–	–	–	–	–	–	–	–	–	–	–	1
Rubus idaeus		1		–	–	–	–	–	–	–	–	–	–	–	+
Rubus pubescens	4	1		–	–	–	–	–	–	–	–	–	–	–	1
Thuidium recognitum			2	+	–	–	–	–	–	–	–	–	–	–	+
Viburnum edule	4	1		–	–	–	–	–	–	–	–	–	–	–	+
Fragaria virginiana		1		–	–	–	–	–	–	–	–	–	–	–	+
Urtica dioica		1		–	–	–	–	–	–	–	–	–	–	–	+

Stellaria longifolia				–	–	–	+	–	+	–	+	+	+	–	2
Scapania irrigua				–	–	–	+	–	–	–	–	+	+	–	–
Carex tenuiflora				–	+	–	–	–	+	–	–	+	+	–	+
Carex rostrata				–	–	–	–	–	–	+	+	+	+	3	1
Brachytheciom turgidum				–	–	–	–	–	–	–	+	+	+	–	–
Cephalozia bicuspidata			2	–	–	–	–	–	–	–	–	+	–	–	–
Cincidium stygium		1		–	–	–	–	–	–	–	–	+	–	–	–
Lemna trisulca		1		–	–	–	–	–	–	–	–	+	–	–	–
Leptodictyum riparium				+	–	–	–	–	–	–	+	+	+	–	–
Plagiomnium drummondii				–	–	–	–	–	–	–	+	+	+	–	+
Rhinanthus borealis		1		–	–	–	–	–	–	–	–	+	–	–	–
Rhizomnium pseudopunctatum				–	–	–	–	–	–	–	+	+	–	–	–
Riccardia latifrons			2	–	–	–	–	–	–	–	–	+	–	–	–
Rumex species				–	–	–	–	–	–	–	+	+	+	–	+
Salix planifolia	3			–	–	–	–	+	–	–	–	+	–	–	–
Trifolium repens		1		–	–	–	–	–	–	–	–	+	–	–	–
Callergon obtusifolium			2	–	–	–	–	–	–	–	+	+	–	–	–
Carex magellanica				–	–	–	–	–	–	–	+	–	–	–	–
Salix discolor	4			–	–	–	–	–	–	–	+	+	–	–	–
Scutellaria galericulata		1		–	–	–	–	–	–	–	+	–	–	–	–
Orchis rotundifolia		1		–	–	–	–	–	–	–	–	+	–	–	–
Lonicera involucrata	4	1		–	–	–	–	–	–	–	–	+	–	–	–
Salix candida	4			–	–	–	–	–	+	–	–	+	+	–	–
Habenaria viridis		1		–	–	–	–	–	–	–	–	+	–	–	–

Poa pratensis		1		–	–	–	–	–	–	–	–	+	–	–	–
Salix bebbiana	4	1		–	–	–	–	–	–	–	–	+	–	–	–
Stellaria crassifolia		1		–	–	–	–	–	–	–	–	+	–	–	–
Sphagnum centrale				+	–	–	–	–	–	–	–	+	+	–	–
Carex lacustris			2	–	–	–	–	–	+	–	–	+	–	–	–
Pinguicula vulgaris		1		–	–	–	–	–	–	–	–	+	–	–	–
Carex brunnescens				–	–	–	–	+	–	–	–	+	–	–	+
Calliergon giganteum			2	–	–	–	–	–	–	–	+	+	–	–	–
Hippuris vulgaris				–	–	–	–	–	–	–	+	+	–	–	–
Herzogiella turfacea		1		–	–	–	–	–	–	–	–	+	–	–	–
Salix pyrifolia	2			–	–	–	–	–	–	–	–	+	–	–	–
Sphagnum wulfianum		1		–	–	–	–	–	–	–	–	+	–	–	–
Sphagnum fimbriatum		1		–	–	–	–	–	–	–	–	+	–	–	–
Alnus rugosa	3			–	–	–	–	–	–	–	–	+	–	–	–
Lophocolea heterophylla				–	–	–	–	–	–	–	+	+	–	–	–
Ranunculus gmelinii			2	–	–	–	–	–	–	–	+	–	–	+	–
Calliergon richardsonii		1		–	–	–	–	–	–	–	+	–	–	–	–
Campylium chrysophyllum		1		–	–	–	–	–	–	–	+	–	–	–	–
Peltigera membranacea		1		–	–	–	–	–	–	–	+	–	–	–	–
Sium suave		1		–	–	–	–	–	–	–	+	–	–	–	–
Plagiomnium ellipticum				–	–	–	+	–	–	–	+	+	+	–	–
Carex prairea				–	–	–	–	–	–	–	1	+	+	–	–
Poa palustris				–	+	–	–	–	–	–	+	+	+	–	–
Cephalozia pleniceps				–	–	–	–	–	–	–	+	+	+	–	–

Galium trifidum			+	–	–	–	–	+	–	2	+	+	–	+
Drepanocladus aduncus			–	–	–	–	+	–	–	1	+	+	1	+
Utricularia vulgaris			–	–	–	–	–	–	–	+	+	+	–	–
Potentilla palustre			+	–	–	–	–	+	–	1	+	1	1	1
Salix pedicellaris	4		–	–	–	–	+	+	+	1	1	1	+	–
Plagiochila porelloides			–	–	–	–	–	–	–	–	+	+	–	–
Carex interior			–	–	–	–	–	–	–	–	+	+	–	–
Drepanocladus vernicosus			–	–	–	–	–	–	–	1	+	1	–	–
Eriophorum viridi-carinatum			–	–	–	–	–	–	–	–	+	+	–	–
Campylium stellatum			–	–	–	–	–	–	–	–	+	+	–	–
Triglochin maritima			–	–	–	–	–	–	–	–	+	2	–	–
Drepanocladus revolvens			–	–	–	–	–	–	–	–	+	+	1	–
Habenaria hyperborea			–	–	–	–	–	–	–	–	+	+	–	–
Carex lasiocarpa			–	–	–	–	–	–	+	+	–	+	3	–
Glyceria pulchella		1	–	–	–	–	–	–	–	–	–	+	–	–
Meesia triquetra			–	–	–	–	–	+	–	–	–	+	–	–
Meesia uliginosa		1	–	–	–	–	–	–	–	–	–	+	–	–
Sphagnum obtusum			–	–	–	–	–	–	+	–	+	+	1	–
Sphagnum subsecundum		2	–	–	–	–	–	–	–	–	–	+	–	–
Utricularia intermedia			–	–	–	–	–	–	–	–	+	1	1	–
Carex diandra			–	–	–	–	–	–	+	+	+	1	+	–
Equisetum scirpoides		1	–	–	–	–	–	–	–	–	–	–	+	–
Phragmites australis		1	–	–	–	–	–	–	–	–	–	–	+	–
Polygonum coccineum		1	–	–	–	–	–	–	–	–	–	–	+	–

Potamogeton gramineus	1		–	–	–	–	–	–	–	–	–	–	+	–
Typha latifolia	1		–	–	–	–	–	–	–	–	–	–	+	–
Habenaria dilatata			–	–	–	–	–	–	–	–	–	+	–	–
Sarracenia purpurea			–	–	–	–	–	–	–	–	–	1	–	–
Tofieldia glutinosa		2	–	–	–	–	–	–	–	–	–	+	–	–
Eriophorum gracile			–	–	–	–	–	–	+	–	–	+	1	–
Chamaedaphne calyculata			–	–	–	–	–	–	–	–	–	+	–	–
Drepanocladus lapponicus			–	–	–	–	–	–	–	–	–	+	–	–
Drosera anglica			–	–	–	–	–	–	–	–	–	+	–	–
Pedicularis parviflora			–	–	–	–	–	–	–	–	–	+	–	–
Rhynchospora alba		2	–	–	–	–	–	–	–	–	–	+	–	–
Lysimachia thyrsiflora			–	–	–	–	–	–	–	–	+	+	–	–
Cephalozia macrostachya	1		–	–	–	–	–	–	–	–	–	+	–	–
Cicuta maculata			–	–	–	–	–	–	–	–	+	+	–	–
Utricularia minor			–	–	–	–	–	–	–	–	–	+	–	–
Drosera linearis	1		–	–	–	–	–	–	–	–	–	+	–	–
Geocaulon lividum	1		–	–	–	–	–	–	–	–	–	+	–	–
Menyanthes trifoliata			–	–	–	+	–	–	+	+	+	3	–	–

Many of the above mentioned species are not typical of peatlands but are generally associated with mineral soil or swamps, but yet peat depths suggested a carbon accumulating system. Such peatlands (or swamps) may have been created by the combination of undulating underlaying topography, resulting water channels, and/or possibly changes in hydrology caused by anthropogenic interference such as road building or seismic line cutting.

TWINSPAN groups 2 (n = 5) is characterized by the presence and high average abundance of *Pleurozium schreberi* and tall (> 10m) *P. mariana*. Group 2 has the highest abundance (3) of tall (> 10 m tall) *P. mariana* while groups 1 and 3 have an average abundance of 2 and 1, respectively. Only traces of tall spruce (> 10 m tall) are present in groups 4 and 5, and none in the other groups. The only species restricted to group 2 is *Rubus pubescens* at a trace value. Group 2 has the second lowest species mean of 19.20 species (Fig. 3.3). Other species present at low average abundance values, but not restricted to the group, are *Dicranum polysetum, Ledum groenlandicum* (< 0.5 m tall), *Pleurozium schreberi, Vaccinium vitis-idaea* (< 0.5 m tall), *Cladonia* species, *Hylocomnium splendens*, and *Pohlia nutans*.

Generally, a tree height of > 10m in peatlands is associated with peat plateaus (Halsey & Vitt, 1996); however, only two of the five sites in group 2 were underlain the non-permafrost sites suggested that the community type is a conifer swamp, but typical swamp flora was not present. Sites in group 2 may be descriptively classified as dry, feathermoss sites (peatlands) with high canopy closure by tall (> 10m) *P.mariana*.

TWINSPAN group 3 (n = 2) is characterized by the high abundance of *Cladina mitis* and *Ledum groenlandicum*, *Vaccinium vitis-idea*, and *Rubus chamaemorus*. Compared to group 1 and 2, *Sphagnum fuscum* is present in group 3. None of the species in group 3 are restricted to the group.

If the high abundance of *Cladina mitis* and the presence of other lichens such as *C. stellaris, C. rangiferina, Cladonia* species, and *Icmadophila ericetorum*, and the presence of *S. fuscum* are used as surrogates for dryness, group 3 is the driest group.

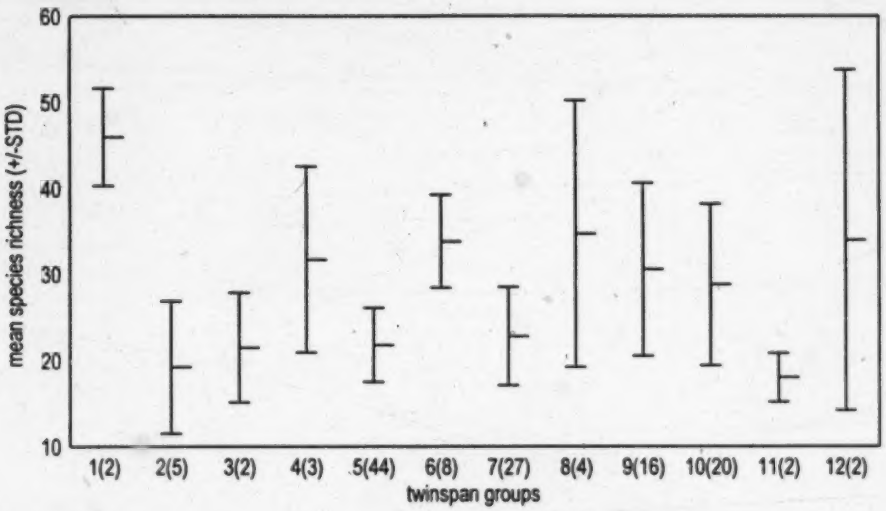

Figure 3.3. Mean site species richness (+/- standard deviation) for TWINSPAN groups. Number in parenthesis equals the number of plots per TWINSPAN group.

The low abundance of *P. mariana* also suggests a more open canopy compared to groups 1 and 2.

TWINSPAN group 4 (n = 3) is characterized by the high abundance of *Vaccinium vitis-idaea* (< 0.5 m) while all other species present have lower average abundance values. Compared to groups 1 - 3, tall (> 10 m) *P. mariana* is only present in trace amounts, while shorter trees are present at average abundance values of 2. The only species restricted to the group is *Juncus bufonicus*. Other species present at average abundance values higher than a trace are *Ledum groenlandicum*, *Pleurozium schreberi*, *Rubus chamaemorus*, *Sphagnum fuscum*, *S. angustifolium*, *Vaccinium oxycoccos*, *Carex aquatilis*, *Aulacomnium palustre*, *Betula glandulosa*, *Sphagnum warnstorfii*, and *Tomenthypnum nitens*.

TWINSPAN group 5 (n = 44) is characterized by the high abundance of *Ledum groenlandicum* and *Sphagnum*. The *Sphagnum* species present at higher average abundance values than trace are *S. fuscum*, *S. magellanicum* and *S. angustifolium*.

P. mariana (from < 0.5 m to 10 m tall), *Vaccinium vitis-idaea*, and *Rubus chamaemorus* are present at average abundance values of 2, while *Cladina mites*, *Pleurozium schreberi*, and *Chamaedaphne calyculata* are present at 1.

Most of the plots within this TWINSPAN group supported growth of stunted *P. mariana* and sometimes few scattered *Larix laricina*. The later is only present as a trace average abundance value. Peatlands falling within group 5 appear to be *Sphagnum*-dominated bogs and poor fens.

Species restricted to the group are *Equisetum palustre*, *Peltigera scabrosa*, *Cetraria nivalis*, *Pinus banksiana*, *Vaccinium myrtilloides*, *Amblystegium serpens*, *Maianthemum canadense*, *Empetrum nigrum*, *Dicranum scoparium*, *Sphagnum lindbergii*, *Plagiomnium medium*, and *Salix pedicellaris*.

TWINSPAN group 6 (n = 8) is characterized by the high abundance of *S. angustifolium* and short (0.5 to 2 m tall) *P. mariana*. Shorter *P. mariana* (< 0.5 m tall) are present at an average abundance of 1 while taller *P. mariana* (2 - 10 m tall) are present at an average abundance value of 2. *Larix laricina* are present at average

abundance values of 1 and 2 for trees < 0.5 m to 10 m tall, while trees over 10 m tall are rarer. Overall, group 6 is the group with the highest abundance of *L. laricina*.

Other species present at average abundance values of 1 and 2 are *Ledum groenlandicum, Vaccinium vitis-idaea, S. magellanicum, Vaccinium oxycoccos, Smilacina trifolia, Carex aquatilis, Aulacomnium palustre, Betula glandulosa, Tomenthypnum nitens,* and *Carex limosa*.

Species restricted to the group are *Anastrophyllum minutum, Ranunculus lapponicus, Pedicularis groenlandica, Cephalozia hampeana*, and *Myurella julacea*.

TWINSPAN group 7 (n = 27) is characterized by low abundance averages of 1 and trace for *P. mariana* and only trace for *L. laricina*. Average abundance values are 2 for S. *magellanicum,* and 1 for *S. fuscum* and *S. angustifolium,* respectively; however, combined species values show a high *Sphagnum* average abundance value. Species present at an average abundance of 2 are *Vaccinium oxycoccos, Smilacina trifolia,* and *Andromeda polifolia*. Species restricted to the group are *Sphagnum majus, Epilobium ciliatum, Spirodela polyrhiza, Ledum palustre, Scorpidium scorpioides* and *Polytrichum juniperinum*.

TWINSPAN group 8 (n = 4) is characterized by the presence and average abundance of 2 for *Carex aquatilis, Calamagrostis canadensis, Calla palustris,* and *Galium trifidum*. Combined average abundance values for the graminoids suggests that the group represents graminoid dominated peatlands, and species such as *C. palustris* further suggest that peatlands in this group have a fairly wet moisture regime. Other species present at average abundance values of 1 are *Aulacomnium palustre, Bryum pseudotriquetrum, Betula glandulosa* (< 0.5m tall and 0.5 - 2 m tall), *Equisetum fluviatile, Climacium dendroides, Carex prairea, Drepanocladus aduncus, Potentilla palustre, Salix pedicellaris,* and *Drepanocladus vernicosus*.

Species restricted to the group are *Carex paupercula, Scutellaria galericulata, Calliergon richardsonii, Campylium chrysophyllum, Peltigera membranacea,* and *Sium suave*.

TWINSPAN group 9 (n = 16) is characterized by a high average abundance

values (3) for *Carex aquatilis,* but *Calamagrostis canadensis* and *Carex limosa* can also be present. *Sphagnum angustifolium, Smilacina trifolia,* and *Calla palustris* are present at average abundance values of 2. Species contributing to the shrub layer are *Salix pedicellaris* (< 0.5 m tall), *Betula glandulosa* (< 2 m tall), and *Vaccinium oxycoccos.* Trees species present at low abundance are *L. laricina* but occasionally *P. mariana* can be present. The group is defined by species that prefer or are restricted to wetter conditions and by low abundance values for tree.

Eighteen species, the most of all groups, are limited to group 9. Some of the species are *Cephalozia bicuspidata, Riccardia latifrons, Orchis rotundifolia, Habenaria viridis, or Pinguicula vulgaris.*

TWINSPAN group 10 (n = 20) is characterized by high abundance of *Menyanthes trifoliata* and *Andromeda polifolia.* In addition to A. *polyfolia, Vaccinium oxycoccos* and *Betula glandulosa* make up the shrub layer.

Some of the species restricted to the group are *Meesia uliginosa, Sarracenia purpurea, Tofieldia glutinosa, Drepanocladus lapponicus, Drosera anglica, D. linearis,* and *Rhyncospora alba.*

The group represents fens that are not densely treed and have a high moisture regime. *Triglochin maritima,* present in group 10, generally grows in somewhat richer fens and is often used as indicator to identify site richness (e.g. Harris et al., 1996). Species such as *Drosera* are known to be sensitive to competition, especially shade, and may indicate that species density of other vascular plants is probably relatively low. Groups 10 and 11 appear to be separated based on the presence of *Carex rostrata* at abundance value 2 for group 11.

TWINSPAN group 11 (n = 2) is characterized by high abundance values for *Carex rostrata, C. lasiocarpa* and *Drepanocladus fluitans.* The presence of the two *Carex* spp. in addition to *Drepanocladus fluitans* indicates that the sites are water saturated on a more permanent basis. Plots in the group were located in areas that are typically mapped as part of lakes (Horsetail Lake and Goodwin Lake). It appears that during dry years draw-down is severe and sedges establish themselves (can be seen for

some lakes as identified in Forest et al., 2000). On-site peat composition analysis clearly showed graminoid peat as expected in the presence of *C. lasiocarpa*. *C. lasiocarpa* is well known to form extensive mats at margins of lakes in generally water-saturated conditions.

Other species in the group that often grow on the margins of lakes or marshes were *Typha latifolia* and *Phragmitis australis*.

TWINSPAN group 12 (n = 2) is characterized by the high abundance of *Calamagrostis canadensis* and species that are more typical of beaver meadows (areas that were flooded by beaver dams in the past but are now drained and vegetated). Although peat depth is >50 cm, species such as *Rumex* spp. and *Rubus acicularis* and DWM (down woody material) suggest that sites in the group were disturbed at one time. Species such as *Alnus rugosa*, *Salix* spp. and *Ribes* spp. suggest that the group is more similar to a shrubby swamp that to a true peatland (Harris et al., 1996).

Congruency of TWINSPAN groups and AWI peatland types

Congruency of AWI classification and TWINSPAN groups can be important in respect to peatland management and conservation. If the two scales, TWINSPAN groups at the local scale and AWI at the landscape scale, are congruent, management and conservation approaches can be blanketed over a large area; whereas if the two scales differ, management and conservation becomes much more intricate and should be based on individual site assessments.

Although the number of AWI peatland types and TWINSPAN groups sampled was rather small (only 98 plots or 1.6% of 6,119 peatland polygons mapped), congruency assessment of AWI peatland types and TWINSPAN groups strongly suggested that most AWI peatland types were not congruent with TWINSPAN groups (Table 3.2).

Local landform modifiers (internal lawns (I); collapse scars (C); internal lawn(s) with island(s) of forested peat plateau (R); or none of the previous features (N); or if the tree canopy cover was <6%, shrub (S) or graminoid (G) dominated) may

Table 3.2. Congruency of on-ground floristic groups (TWINSPAN analysis groups) with AWI classes at the landscape level. 'n' represents the number of AWI types per TWINSPAN group. The fourth letter in the 4-letter code describes local landform modifiers: modifiers are C - collapse scar; R - internal lawn(s) with island(s) of forested peat plateau; I - internal lawn(s); or N, if none of the previous modifiers. If tree canopy closure was < 6%, then local modifier can be S - shrub cover > 25%, or G - graminoid cover > 25%.

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TWIN-SPAN	AWI polygons	AWI type	number/ type	% of group 3 letter	% of group 4 letter
Group 2	n=2	BTN N	1	100	50
		BTN R	1		50
Group 4	n=3	FTN I	3	100	100
Group 5	n=34	BTN I	6	71	18
		BTN N	16		47
		BTN R	2		6
		FON S	1	3	3
		FTN I	3	24	9
		FTN N	5		15
		FTP N	1	3	3
Group 6	n=5	FON S	1	20	20
		FTN I	1	80	20
		FTN N	3		60
Group 7	n=25	BTN I	7	44	28
		BTN N	2		8
		BTN R	2		8
		FON S	10	40	40
		FOP N	1	4	4
		FTN I	1	12	4
		FTN N	2		8
Group 9	n=11	BTN N	1	18	9
		BTN R	1		9
		FON S	2	18	18
		FTN N	7	64	64
Group 10	n=18	FON S	2	11	11
		FOP N	4	22	22
		FTN I	1	56	6
		FTN N	8		44
		FTN R	1		6
		FTP N	2	11	11

create a problem when comparing AWI peatland types and TWINSPAN groups because permafrost features can not be identified as such in floristic analysis. If local landform modifiers are not considered, that is AWI peatlands are identified by wetland class (e.g. bog, B), vegetation modifier (e.g. treed, T), and wetland complex modifier only (e.g. neither patterning nor permafrost present, N), then the two scales are slightly more congruent but still show large discrepancies (Table 3.2).

TWINSPAN group 2 (n=5) is defined by high abundance of *P. schreberi* and tall *P. mariana* typical of permafrost sites; however, not all plots in TWINSPAN group 2 were permafrost underlain. Only two plots are included in the congruency assessment and while one was a permafrost plot (depth to permafrost was 35 cm) that corresponded to the mapped AWI type of BTNR, the other plot was not permafrost underlain and was mapped as BTNN. The latter plot was a bog island in a fen matrix. Floristically, regardless of permafrost, the two plots are similar in respect to tree height and abundance and to abundance of *P. schreberi*. Congruency assessment shows that TWINSPAN group 2 corresponded to two AWI peatland type if the local landform modifier was considered but only to one type if the local landform modifier was not considered (Table 3.2).

Only one AWI peatland type, FTNI, falls in TWINSPAN group 4, but not all FTNI classified polygons are in group 3. Group 3 has the highest abundance of lichens of all groups, a *S. fuscum* layer, and few trees. Perhaps a high lichen cover and *S. fuscum* is not the typically dominant flora expected in internal lawns in treed fens (FTNI); however, age (time since absence of permafrost) and stage of succession may determine species assemblage and abundance at such sites (D. Beilman, pers. com.).

If age and stage of succession determines species assemblage and abundance, and AWI classification is based on landforms and identifiable vegetation layers (called vegetation modifiers in the AWI classification), then AWI peatland types such as FTNI will never fall into one TWINSPAN group. Internal lawns may also be located in fens with different moisture and nutrient regimes. For example, an internal lawn in an intermediate-rich fen will probably be influenced differently than an internal lawn in a

poor fen and plant species assemblage would more than like reflect such differences. Therefore, peatland type FTNI can potentially fall into several TWINSPAN groups based on floristics that in turn are determined by environmentally variables such moisture, nutrients, pH, or shade (Belland & Vitt, 1995).

Seven different AWI peatland types fall into TWINSPAN group 5. While AWI peatland types in the group vary from shrubby fen (FONS) to permafrost underlain bogs (BTNR), 47% are treed bogs (BTNN) and 15% are treed fens (FTNN). Group 5 appears to include bogs and poor fens based on the high abundance values of *Sphagnum*, stunted *P. mariana*, and ericaceous shrubs. Fen richness (nutrients and/or species) is not identifiable at the landscape scale, and treed fens (FTNN), patterned fens (FTPN), or even a shrubby fen (FONS) may all be floristically similar, although classified as different AWI peatland types based on landform and the vegetation modifier. Fens in TWINSPAN group 5 may all be poor fens, regardless of patterning, shrubby or treed. As already discussed above (TWINSPAN group 2), species assemblage and abundance of internal lawns can be influenced by the surrounding matrix and the age of the internal lawn; and thus, it can make sense that AWI peatland types BTNI and FTNI are included in group 5. BTNI and FTNI peatland types contribute over 26% while AWI peatland types FTPN, FTNN, FONS, and BTNN contribute almost 68% to TWINSPAN group 5. The remaining 6% are made up by BTNR.

If congruency is assessed without local landform modifiers, four AWI peatland types fall into TWINSPAN group 5. Overall, it appears that AWI peatland types are not congruent with TWINSPAN group 5.

Three AWI peatland types, FONS, FTNI, and FTNN, fall into TWINSPAN group 6. As above, the internal lawn is placed into group 6 based on vegetation and not landform. FONS and FTNN are separated based on vegetation modifiers in the AWI classification; however, if trees are small but present in addition to a well developed shrub layer, they may not be noticeable on aerial photographs. Group 6 is characterized in TWINSPAN by the presence of trees, especially high average

abundance values for shorter trees, and ericaceous shrubs. AWI peatland types may have had over 6% of short trees in the shrub layer but they may have not been visible on aerial photographs.

Seven AWI peatland types fall into TWINSPAN group 7. Group 7 is characterized by low abundance values for trees and high abundance values for *Sphagnum*. Peatland type FONS represents 40% while treed AWI types, including AWI peatland types that have a permafrost modifier, represent 56% of group 7. Peatland type FOPN (open patterned fen) represents 4%. Here again, vegetation and permafrost modifiers are not congruent with TWINSPAN groups. If the local landform modifier is ignored, four AWI peatland types fall into TWINSPAN group 7.

AWI peatland type FONS could potentially be a good match; however, AWI peatland types are not differentiated based on bryophyte cover and group 7 is partially characterized by high abundance values for *Sphagnum*.

Four AWI peatland types fall into TWINSPAN group 9 that is characterized by high average abundance values of graminoids and low shrubs and low average abundance of trees. Overall, AWI peatland types BTNN, BTNR, and FTNN do not seem to belong to the group. Peatland type FONS could be an acceptable type in group 9. Perhaps the relatively low cutlevel for classifying peatlands as treed (> 6% trees present = treed) in the AWI classification contributes to the dichotomy between AWI peatland types and TWINSPAN groups.

Six AWI peatland types fall into group 10 that is characterized by species such as *Menyanthes trifoliata* or *Tofieldia glutinosa* that prefer wetter and/or richer conditions (Moss, 1983). Plots in the group are not densely treed. All AWI peatland types that fall into the group are fens but some are patterned, open, treed, or have permafrost modifiers. Even if local landform modifiers are ignored, AWI peatland types are not congruent with the floristic group.

Overall, AWI peatland types are not congruent with TWINSPAN groups and peatlands can not be managed by using AWI classification only. Several factors contribute to the incongruity; a) AWI classification is based on landform, vegetation

and permafrost modifiers whereas TWINSPAN groups are clustered based on floristics; b) nutrient and moisture regimes influence plant distribution and abundance but AWI classification was developed for inventory purposed using aerial photograph interpretation only (it is not possible to assess nutrient or moisture regime on aerial photographs); c) cutlevels, especially if the trees are small, are rather low at 6% for the definition of a treed peatland and may group too many peatland types together; and d) habitat heterogeneity at the local scale differs from landscape scale heterogeneity; i.e. local scale heterogeneity may disappear at the landscape scale.

It should be noted that scale is more than likely the major reason for ecological variety within AWI peatland types and not human error or short-comings in the AWI classification. For example, a peatland of approximately 60 ha such as a treed fen (FTNN) may appear very homogenous on a 1:50,000 or 1:20,000 aerial photograph, but on a 1:1 scale (i.e. on-ground, site specific scale) local site differences can easily be detected. A given peatland may also have pockets of different peatland types that were too small to either detect on aerial photographs or to map during the inventory. Local site differences or pockets of different peatland types provide habitat for different species that may be indicative of sites conditions.

It is important for land managers to recognize these differences when assessing sites, especially when evaluating a sites's potential for peat harvesting or conservation.

Flora - ANHIC and local rarity and species richness

A total of 255 plant species, including vascular plants, bryophytes and lichens, were found (Appendix A), of which eight are considered rare (Table 3.3) based on the ranking used by ANHIC (Gould, 1999). A total of 99 species, almost 39%, were considered locally rare based on occurrences of one or two (species are identified in Table 3.1).

Over 63% of the ANHIC rare species were in TWINSPAN peatland type 10, while 9% were in group 5, 7, and 9, respectively, and just over 4.5 % in groups 8 and

Table 3.3. Plant species rarity based on Gould (1999), association with peatland type and species richness.

Species	Rank	Plots	polygon ID number	AWI type	species in plot
Carex lacustris	S2 G5	2C	5963	FONS	34
Carex rostrata	S2 G5	55	5734	FONS	18
Carex rostrata	S2 G5	67	2945	FONG	16
Carex rostrata	S2 G5	51C	6852	FTPN	28
Drosera anglica	S2 G5	52	7006	FOPN	57
Drosera anglica	S2 G5	66B	3078	FOPN	25
Drosera anglica	S2 G5	51D	7168	FOPN	39
Drosera anglica	S2 G5	51C	6852	FTPN	28
Drosera linearis	S2 G4	52	7006	FOPN	57
Sarracenia purpurea	S1S2 G5	76	9568	FTNR	27
Sarracenia purpurea	S1S2 G5	52	7006	FOPN	57
Sarracenia purpurea	S1S2 G5	43A	453	FTNN	24
Sarracenia purpurea	S1S2 G5	66B	3078	FOPN	25
Sarracenia purpurea	S1S2 G5	53B	5669	FTPN	29
Sarracenia purpurea	S1S2 G5	51D	7168	FOPN	39
Sarracenia purpurea	S1S2 G5	51C	6852	FTPN	28
Sarracenia purpurea	S1S2 G5	37	6274	FTNN	28
Sarracenia purpurea	S1S2 G5	32A	9276	FOPN	38
Sphagnum contortum	S2 G5	29	7355	FONS	52
Sphagnum contortum	S2 G5	3B	6114	FONS	27
Sphagnum fimbriatum	S2S3 G5	71B	131	BTNR	28
Sphagnum lindbergii	S2S3 G5?	63A	2589	BTNR	22

Rank (G=global; S=Alberta) in Alberta are defined as follows in Gould (1999):
G1 S1: </= 5 occurrences or only few remaining individuals.
G2 S2: 6-20 occurrences or with many individuals in fewer occurrences.
G3 S3: 21-100 occurrences may be rare and local throughout its range (may be abundant in some locations or may be vulnerable to expirtation because of some factors because of its biology).
G4 S4: apparently secure under present conditions, typically > 100 occurrences but may be fewer with many large populations; may be rare in parts of its range, especially peripherally.
G5 S5: demonstrably secure under present conditions, > 100 occurrences, may be rare in parts of its range, especially peripherally. (G5? = not yet ranked)

11, respectively. The TWINSPAN group with the highest number of rare ANHIC species also had the plot with the highest number of species, or richness. The highest number of species, 57 species, per site was recorded in an open patterned fen in TWINSPAN group 10. It appears that 50% of the TWINSPAN peatland types provide habitat to rare species and/or have a high mean species richness (Fig. 3.3). Three of the above six peatland types (groups 8, 9, 12) that provide habitat to rare species also have a high (>30 spp.) mean species richness.

Ninety-nine species out of 255 are considered locally rare based on a species occurrence of less than or equal to two. Sixty-three species (almost 27%) occurred only once and 36 species (14%) occurred only twice (Fig. 3.4).

Most locally rare species, 22%, were found in TWINSPAN group 9 while no locally rare species were found in TWINSPAN group 3. TWINSPAN groups 12 and 1 provided habitat to 17% and 12% of the locally rare species, respectively.

Mean species diversity values and standard deviations per TWINSPAN group indicates that peatlands at the site level vary highly as previously shown for bryophytes by Vitt et al. (1995), and that habitat uniqueness is important when assessing peatlands on an ecological basis. Here, it is assumed that habitat uniqueness determines species distribution in most cases. Habitat uniqueness may also be described as a species's ecological niche that can range from narrow to broad depending if the species is a specialist or generalist. Specialists may be restricted in habitat distributions but may be present in large local abundances (Benayas et al., 1999). A good example in this study are species such as *Drosera linearis* or *Sarracenia purpurea*. *D. linearis* was only recorded once in 135 plots but had a high abundance value while *S. purpurea* was recorded eleven times with high abundance values in nine cases. While the above studies are based on plant species richness and rarity, other organisms, especially invertebrates, may follow similar patterns.

Sites in group 10 provided habitat to seven species of carnivorous plants. Only ten carnivorous plant species are known in Alberta, and in 20 sites 29 occurrences of carnivorous plants were recorded. Sites in this group can be identified by the presence

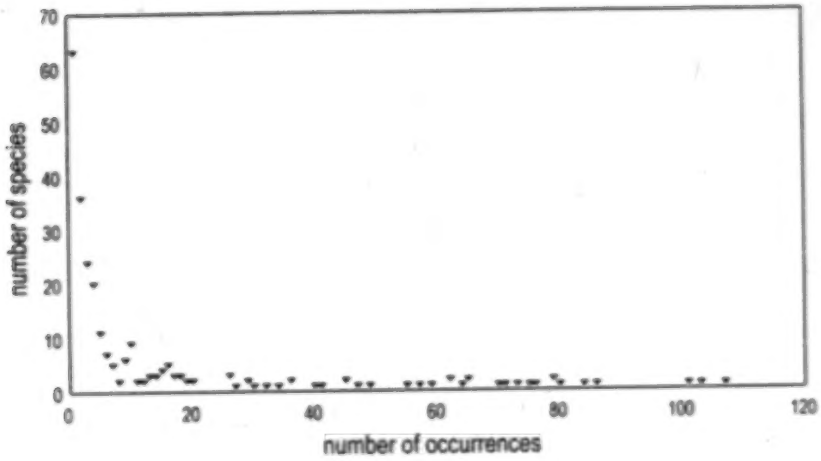

Figure 3.4. Species occurrences within the 135 peatlands sampled: out of 255 species 63 species occurreed only once and 36 species occurred twice.

of *Menyanthes trifoliata* and *Triglochin maritima,* both species are indicative of richer and wetter conditions (Moss, 1994; Harris et al., 1996).

In summary, AWI peatland types and on-ground TWINSPAN peatland types are not congruent and there is no apparent pattern how the two scales can be related.

MANAGEMENT RECOMMENDATIONS

By identifying peatland types on ground level, habitat of rare species, and to a much lesser degree, species richness can be assessed. Assessment of these two factors is important for peatland managers as rarity and species richness are two major criteria used in land resource management.

While TWINSPAN separated the groups into meaningful clusters, it can not replace an on-ground peatland (or wetland) classification. An applied classification would need to be based on more than a 135 plots used in this study and would need to be field tested thoroughly by wetland ecologists. For example, the wetland classification for northwestern Ontario was based on 1,369 plots (Harris et al., 1996) and was extensively field tested (pers. obs.). Northwestern Ontario's wetland ecosystem classification recognizes 36 wetland types (bogs, fens, swamps, and marshes) on-ground that fit into 17 mappable ecosites (Racey et al., 1996). While the wetland classification is specific for the site level, ecosites are mappable units (mapping scales may vary from 1: 10,000 to 1:50,000 (Racey et al., 1996)) for landscape scale management similar to the AWI.

In Alberta we already have mappable units under the AWI classification standards but not a ground level classification for wetlands that is suitable for smaller areas (100 - 100,000 m^2). Because ecosites can be placed within a landscape scale classification system (i.e. a hierarchical system), it is recommended to develop such a classification to ensure meaningful peatland management taking rare species and species richness into consideration. Species richness and rare species habitat can be linked to peatland types as shown above.

In respect to peatland management, resource managers and bog developers (peat

industry) should recognize the degree of difference in scale when assessing peatlands at the landscape level versa site level: 1) Landscape level assessment identifies rare peatland types under the AWI, location of such peatlands, degree of anthropogenic disturbances (especially seismic lines, well sites, and pipelines), and caribou habitat as identified by the Boreal Caribou Committee (see chapter 2 for details); 2) On-ground site assessment identifies ecological peatland types based on indicator species rather than on dominant vegetation groups only; and, 3) Ecological peatland types can be useful in identifying peatland types that provide habitat for rare species.

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CHAPTER IV: MANAGEMENT RECOMMENDATIONS TO THE ALBERTA PROVINCIAL GOVERNMENT

EXECUTIVE SUMMARY

Alberta's peatlands, bogs and fens, cover < 16 % (10.3 million ha) of the province and are located in the green or unsettled area. Currently there is no peatland managing policy for the this area but natural resource industry is rapidly expanding in the north.

Provincially, only one horticultural peat company is currently operating in the green area near the hamlet of Wandering River, but without a peatland policy or management guidelines it can be difficult to operate efficiently.

Other natural resource industries operating in the green area are conventional oil and gas, forestry, oil sands operations (open pit mining and in situ operations), and agriculture. These industries leave a large ecological foot print in the green area that can affect peatlands as well as uplands. A peatland management policy can improve ecological responsibly of such industries and identify potential problem areas.

It was one of the horticultural peat companies that took the initiative to ask for a provincial peatland policy to identify sensitive areas and avoid costly environmental impact assessments when selecting potential bogs for harvesting. Out of this need, the Peat Management Task Force, an association of the peat industry, the University of Alberta, and the provincial government was formed. Its mandate is to provide information and input in respect to peatland management.

Initially a 1:1,000,000 peatland inventory summary map was produced. Peatlands were inventoried and classified based on the Alberta Wetland Inventory Standards, a classification system for aerial photograph interpretation.

While it made sense to use the Alberta Wetland Inventory Standards to assess types and amounts of peatland resources in a large and often inaccessible landscape, the question of how to manage Alberta's peatlands, especially rare species habitats, still remained.

Based on the above needs the Peat Management Task Force decided to support a

study that would answer the above questions. The study was done as a MSc thesis through the University of Alberta. The purpose of the thesis was twofold: 1) to develop an ecological peatland management key and in the process assess peatland resources using the Alberta Wetland Inventory Standards and linear disturbances; and 2) to test if the Alberta Wetland Inventory Standards classification is congruent with on-ground peatland classification based on plant species groups, and if either scale can be used in peatland management and conservation.

In this thesis, a study area (> 12,500 km^2) in the green area rich in peatlands was inventoried and mapped at the 1:50,000 scale and peatland resources, as well as linear disturbances, were assessed. An applied peatland management decision key was developed for resource managers and peat industry. The key, in conjunction with the peatland inventory, can be used to assess peatland types (based on Alberta Wetland Inventory Standards) and abundances at the landscape level, but it is recommended to develop an applied on-ground wetland ecosystem classification system. Results from the study suggested that Alberta Wetland Inventory Standards landscape classification is not congruent with on-site classification and that a provincial wetland ecosystem classification would benefit land managers and industry.

Peatland resource assessment showed that Alberta Wetland Inventory peatland types ranged from common (30%) to rare (< 0.02%) and that only one peatland type was not affected by linear disturbance. Disturbance assessment further showed that the hydrocarbon industry causes the most disturbance in boreal peatlands.

Management recommendations are to manage peatlands as peatland management areas that correspond to Alberta's Natural Subregions, to refuse applications for fuel peat mining, to test applicability of the management key for the rest of the green area, to employ a cumulative effects model, to develop an applied on-ground ecological wetland ecosystem classification system, to identify a given peatland's status of rarity in the digital data base, to keep data bases up to date, to work with the Boreal Caribou Committee on peatland caribou habitat management, to work with natural resource industry (and to ask for their cooperation), to work with the Alberta Natural Heritage Information Centre and

Alberta Fish and Wildlife, to work with the provincial protected areas management framework, and to work with research institutions.

Overall it is recommended that peatlands are managed with involvement from all stakeholders and that 2776 km^2 of peatlands within the study area are protected, leaving 2185 km^2 of peatlands unprotected.

BACKGROUND

Background of Peat Management Task Force and Project

Alberta's peatlands, bogs and fens, cover 16.3 % (10.3 million ha) of the province, (Vitt et al., 1996) most of which are located in the green area (Fig. 4.1). Currently there is no policy for managing peatlands (and other wetlands) in the green area (Alberta Water Resources Commission, 1993), but one of the natural resource industries operating in this area are horticultural peat companies.

Horticultural peat companies in Canada prefer the weakly decomposed *Sphagnum* peat found in bogs and extraction has been increasing steadily over the last 10 years (Joosten, 1995). Provincially, only one horticultural peat company (Sun Gro) is currently operating in the green area near the hamlet of Wandering River; the operation covers approximately 1,800 ha (Tony Cable, pers. com.). Without a peatland policy or management guidelines it can be difficult for a horticultural peat company to operate efficiently and provincial land managers are not able to make recommendations.

In Alberta, the peat industry took a proactive attitude and approached the University of Alberta to assess provincial peatland resources and possible management tactics. Together, they approached the provincial government to become a partner in creating a policy for peatland development and conservation. Out of this need, the Peat Management Task Force (PMTF), an association of the peat industry, the University of Alberta, and the provincial government was formed. Its mandate is "to provide information that will contribute to the orderly development and conservation of peatland ecosystems" (Peat Management Task Force, 1995).

To reach the objective, a *Peatland Summary Map* at 1:1,000,000 (Vitt, 1992) and

Fig. 4.1. Green area of Alberta covers 53% of the province or approximately 250,428 km^2. The study area covers only 3.6% of the green area in north-eastern Alberta.

an inventory document *Peatland Inventory of Alberta* (Vitt et. al, 1996) were produced in the initial phase. Based on the map and inventory, a region with a high concentration of peatlands was chosen to start the next phase, Phase II, of the PMTF's objective.

Part of the PMTF's objective was approached as a MSc thesis and a summary of this thesis, especially management recommendations for the provincial government are given here. Detail of methods and ecological descriptions in respect to management key and mapping are given in Chapter 2 (Forest, 2000). Resulting inventory maps (Forest et al., 2000) (in paper format or digital format) are available through Alberta Environment, Resource Data Division, Edmonton, Alberta.

The objective of this thesis was: 1) to develop an applied ecological peatland management key for the Green area and in the process assess peatland resources using the Alberta Wetland Inventory (AWI) Standards (Halsey & Vitt, 1996) and linear disturbances; and 2) to test if the AWI peatland landscape classification is congruent with on-ground floristic groups, and if either scale can be used to manage peatlands.

Study Area, Peatland Resource Inventory, and Maps

A study area of 12,556 km^2 (Fig. 4.2) or approximately 3.6% of the green area was chosen based on peatland density as identified on the Alberta peatland inventory summary map (1:1,000,000) (Vitt, 1992). The map indicated a high concentration of peatlands within north-eastern and north-central Alberta's Aspen Parkland and Boreal Forest. Sample locations are identified in Fig. 4.2 and in the digital data base.

Alberta Wetland Inventory (AWI) Standards (Halsey & Vitt, 1996) were used to classify and inventory peatlands within the study area. Under these standards, peatlands are classified by four-letter codes that stand for landscape features that can be identified on aerial photographs (Table 4.1). A detailed overview of peatland types is given in Chapter 2 (MSc thesis, Forest 2000) or in the Alberta Wetland Inventory Standards (Halsey & Vitt, 1996), available through the University of Alberta and Alberta Environment, Edmonton, Alberta, respectively.

Congruency of AWI landscape classification (landscape here refers to the

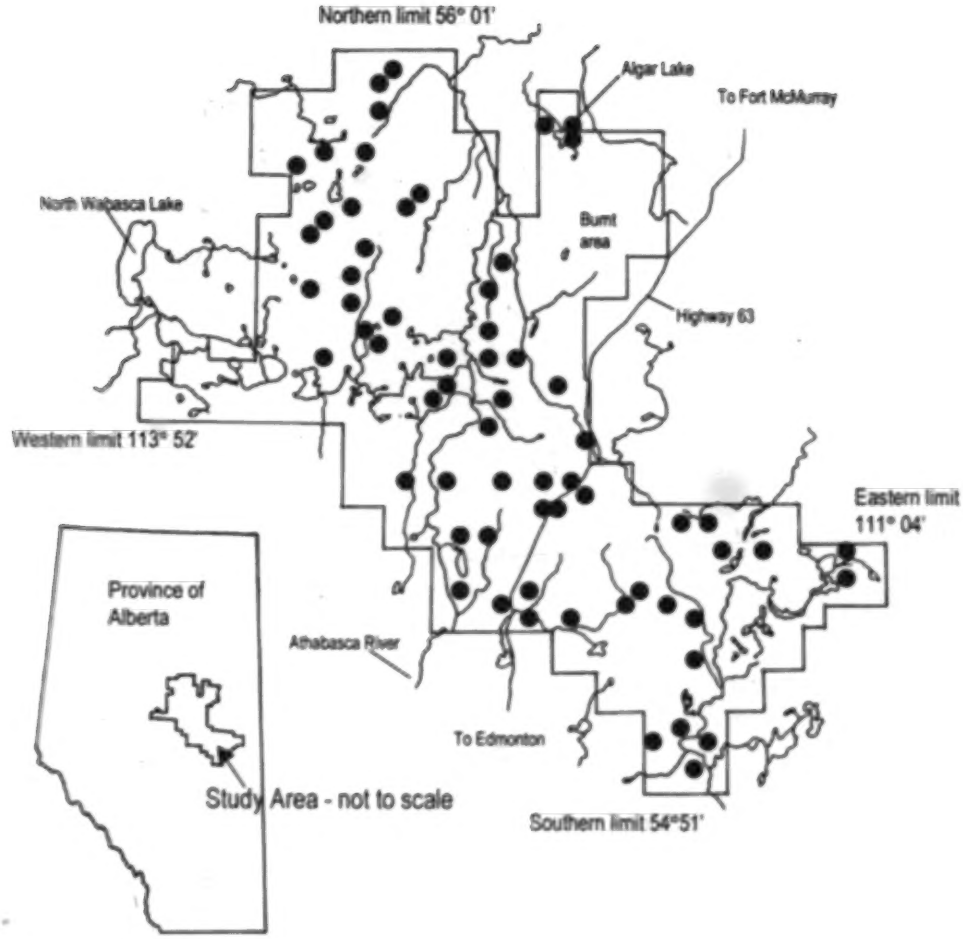

Fig. 4.2. Study area (12,556 km ^{2}) in northeastern Alberta, Canada. Dots represent study locations; one dot may represent more than one site.

Table 4.1. AWI Standards peatland classes used in inventory and classification (table modified from Halsey & Vitt, 1996). A letter from each category is used to classify peatlands to AWI Standards. Examples might be BTNI (bog, treed, no permafrost or patterning, internal lawn) or FONS (fen, open, no patterning or permafrost, shrub dominated).

Landscape Features	Description of Landscape Feature		Letter Code
Wetland Class	bog		B
	fen		F
Vegetation Modifier	forested:	tree canopy closure > 70%	F
	treed (wooded):	canopy closure > 6% but < 70%	T
	open:	tree canopy closure < 6%	O
Wetland Complex Landform Modifier	permafrost present		X
	patterning present		P
	neither permafrost nor patterning present		N
Local Landform Modifier	collapse scar(s)		C
	internal lawn(s) with island(s) of forested peat plateau		R
	internal lawn(s)		I
	none of the above local landform modifiers present		N
	if tree canopy closure was < 6%, then identify graminoid or shrub dominated:		
		shrub cover >25%	S
		graminoid cover > 25%	G

mapping scales of 1:40,000 and 1:15,000; final maps were printed at 1:50,000) with on-ground floristic groups was tested by entering on-ground sampling sites into the GIS data base by UTM references. Site locations in the digital data base were manually checked against aerial photographs that were used in the field. This allowed for identification of AWI polygon classification at the landscape scale to ground data at the local scale. The number and types of AWI classes that fell within one on-ground type were calculated in percent. On-ground floristic groups were determined using TWINSPAN (Hill, 1979, modified by Minchin, 1997), an ecological statistics program.

Within the study area 135 sites were sampled for plant species (vascular plants, bryophytes, and lichens) between June and the end of August, 1996. Sites had at least 40 cm of peat (peat depth is used to classify wetlands as peatlands in the Canadian Wetland Classification System (National Wetlands Working Group, 1988) but in most cases peat depth was greater.

RESULTS

Relative Peatland Type Abundance within Phase II Study Area

GIS analysis of the peatland layer showed that within the study area of 12,556 km^2, almost 5,000 km^2 (40%) are peatlands, 680 km^2 (5%) are other wetlands (swamps, marshes, or shallow open water), and 6,900 km^2 (55%) are mineral soil.

A total of 6,119 peatland polygons larger than 0.5 ha were inventoried; smaller polygons were not identified because of mapping limitations at the 1:50,000 scale. Fifteen different peatland types were mapped according to Alberta Wetlands Inventory (AWI) Standards (Halsey & Vitt, 1996).

Within the study area, the most common peatland types are treed fens (FTNN) and bogs (BTNN). Treed fens (FTNN) (1415 polygons) cover a total of 1473 km^2 (30% of peatland area or 23% of all peatland polygons), while treed bogs (BTNN) (2247 polygons) cover 1362 km^2 (27% of area and 37% of all peatland polygons) (Table 4.2). BTNNs are the most common type by the number of polygons and FTNN by surface area.

Table 4.2. Summary of the 15 AWI peatland types** inventoried: number of polygons per peatland type and area (in ha and in km2) and respective percentages.

peatland type	total polygons	area in ha	area in km2	% of total area	% of total polygons	AWI peatland rarity
BTXN	3	96	1	< 1	< 1	**rare**
BFXN	11	138	1	< 1	< 1	
FOPI	2	287	3	< 1	< 1	peatland area
BTXC	36	748	7	< 1	1	is 94 sq. km
BFXC	53	1023	10	< 1	1	or < 2% of
FOPN	56	1848	18	< 1	1	peatlands
FONG	178	2344	23	< 1	3	
FTPN	47	2929	29	1	1	
FTNR	120	16651	167	3	2	**intermediate**
BTNR	189	26070	261	5	3	peatland area
FONS	1198	43689	437	9	20	is 2038 sq. km
FTNI	245	46252	463	9	4	or 41% of
BTNI	319	71142	711	14	5	peatlands
BTNN	2247	136206	1362	27	37	**common**
FTNN	1415	147311	1473	30	23	peatland area is 2835 sq. km
Totals:	6119	496734	4967	100*	100	or 57% of peatlands

* 100 percent of peatlands inventoried; peatlands smaller than 0.5 ha are not included in the above, regardless of area or number of polygons.

** B = bog; F = fen, T = treed, F = forested, O = open, X = permafrost, P = patterned, N = non of the possible modifiers, I = internal lawn, C = collapse scar, G = graminoid dominated, S = shrub dominated

Peatland type FOPI (open, patterned fens with internal lawns) is the least common peatland type by number of polygons (2 polygons) but covers almost 3 km^2 and represents < 0.1% of peatland area and < 0.1% of all peatland polygons. Peatland type BTXN (wooded permafrost bogs without collapse scars) was only mapped 3 times and covers < 1 km^2 and represent < 0.1% of the total peatland area and < 0.1% of all peatland polygons.

Plant Species

A total of 263 species, composed of 141 vascular plant species, 82 moss species, 28 hepatic species, and 12 lichen species (*Cladonia* species were only identified to genus) were identified in the sampled peatlands (species list is available in Forest, 2000). Not all AWI peatland types were sampled because the study area was inventoried and mapped after field sampling and AWI peatland types were not identified at the time. Hence, ground data only exists for 10 peatland types out of 15 types mapped.

The number of species found within a given AWI peatland type ranged from 24 to 25 species in treed patterned fens (FTPN) and from 12 to 53 species in treed fens (FTNN). The most species per site (57 species) were found within a treed fen that had internal lawns (FTNI).

Rare, threatened, or endangered species

Flora: Under the Alberta Natural Heritage Information Centre's *Plant Species of Special Concern* list only eight rare species were identified: three species of *Sphagnum* (peat moss), two species of *Carex* (sedges), and three species of carnivorous plants.

Fauna: Only two animal species that utilize peatlands were identified: The woodland caribou (*Rangifer tarandus caribou*) is on Alberta's Blue List that states that *current knowledge suggests that these species may be at risk* (Alberta Environmental Protection, 1996). The woodland caribou is declared threatened under the *Provincial Wildlife Act* (Alberta Environmental Protection, 1998) and recent studies in Alberta (Bradshaw et al.,

1995; Anderson, 1999) show that woodland caribou prefer treed peatlands as their habitat.

The Whooping Crane (*Grus americana*) is on Alberta's Red List that states that *current knowledge suggests that these species are at risk* (Alberta Environmental Protection, 1996). The Whooping Crane is know to nest in Wood Buffalo National Park but uses peatlands as staging areas during migration.

Linear Disturbance

In peatlands within the study area, linear disturbance of seismic lines stretches over 1,800 km in length (based on 1989 - 1995 coverage received from Alberta Environmental Protection). If a width of 15m is assumed (a 6-8 m seismic line width is used in some sensitive areas but width was not differentiated on the available data set), total linear disturbance in peatlands only (excluding other wetlands and mineral soil) covers > 2821 ha or > 0.5 % of the total peatland surface area (Table 4.3).

If edge effect is calculated based on a 50 m and a 100 m buffer on either side of the middle of the cutline, > 9405 ha (almost 2%) and > 18,810 ha (almost 4%) are disturbed, respectively. If disturbance with buffers is calculated by peatland type, percent disturbance ranges from 0.2 % to 3 %, and from 0.4% to 6%, respectively.

Congruency of AWI Classification and TWINSPAN Species Groups

Congruency of AWI classification and TWINSPAN species groups can be important in respect to peatland management and conservation. If the two scales, TWINSPAN groups at the local scale and AWI at the landscape scale, are congruent, management and conservation approaches can be blanketed over a large area; whereas if the two scales differ, management and conservation becomes much more intricate and should be based on individual site assessments.

Although a larger number of plots than used here would be desirable, the congruency assessment of the AWI peatland types and TWINSPAN groups strongly suggests that most AWI peatland types were not congruent with on-ground species

Table 4.3. Linear disturbance length (in metres) and area based on 15 m seismic line width, with 50 m and 100 n buffer, and respective percent disturbances per peatland type and overall.

peatland type	peatland area in ha	linear dist. in metres	linear dist. area in ha	dist. area in percent	with 50 m buffer, in ha	dist. percent	with 100 m buffer, in ha	dist. percent
FTPN	2929	1099	2	0.1	5	0.2	11	0.4
BFXC	1023	879	1	0.1	4	0.4	9	0.9
FTNR	16651	24938	37	0.2	125	0.7	249	1.5
BTXC	748	1207	2	0.2	6	0.8	12	1.6
FTNN	147311	380246	570	0.4	1901	1.3	3802	2.6
BFXN	138	407	1	0.4	2	1.5	4	3.0
FTNI	46252	141252	212	0.5	706	1.5	1413	3.1
FONG	2344	7256	11	0.5	36	1.5	73	3.1
FOPN	1848	6039	9	0.5	30	1.6	60	3.3
FOPI	287	1026	2	0.5	5	1.8	10	3.6
BTNR	26070	108768	163	0.6	544	2.1	1088	4.2
FONS	43689	187924	282	0.6	940	2.2	1879	4.3
BTNN	136206	598212	897	0.7	2991	2.2	5982	4.4
BTNI	71142	421805	633	0.9	2109	3.0	4218	5.9
BTXN	96	no linear disturbance recorded at the time						
Totals	496638	1881059	2822	1	9405	2	18811	4

groups.

APPLIED PEATLAND MANAGEMENT KEY

A peatland management key (Table 4.4; Figure 4.3) was developed to provide a framework for the provincial government as management and conservation tool. The key was developed based on the 12,556 km^2 area that represents 3.6% of the green area. It should be realized that some regions within the green area are ecologically very different and that the key may not be applicable in these regions.

The peatland management key is a dichotomous key that consists of 17 decision points or couplets soliciting yes or no answers only. The key itself is accompanied with a text version that is more explanatory and should be read first.

Up to decision couplet 8 and 9 for intermediate and common peatland types, respectively, on-ground site assessments are not necessary. At couplets 8 and 9, respectively, a site visit becomes necessary to ascertain presence of rare species and/or diversity. While species rarity and plant diversity is ascertained in the field, horticultural peat harvesting potential can be ascertained at the same time. It is obvious that a peat company would not allocate resources for a rare species assessment without establishing peat quality and therefore economic potential first. Hence, peat companies are not forced to assess ecological values on sites they are not interested in. However, if a company identified a site for development and the site assessment by a professional plant ecologist or botanists shows that rare species are present, or that species diversity is high, then the company should be asked to provide this information for conservation planning. Natural resource industries such as oil and gas should be asked to cooperate in a similar manner.

The decision key is accompanied by a text that explains each decision couplets in more detail. The text is meant to supplement the key and clarify points.

Table 4.4. Peatland Management Key, text part.

How to use the key: Each vertical line is associated with a decision question and a number. The number links the key to the text below that explains each decision couplet in more detail. Decision rules consist of yes/no questions only. Terms like rare, common, or intermediate are explained in the text below and are thoroughly discussed in Chapter 2 (MSc thesis, Forest, 2000).

Decision rules:

1) Peatland type rarity is based on the GIS data base and can be obtained from Table 4.2. Peatland types BTXN, BFXN, FOPI, BTXC, BFXC, FOPN, FONG, FTPN, and FTNR are considered rare because they represent either less than 3.5 % of the total peatland area or less than 2 % of the total number of polygons. All the above peatland types should be protected from development and identified in the GIS data base. If the peatland type is not rare, go to decision 2; if rare, go to 3.

2) Peatlands types that are intermediate in rarity are BTNR, FONS, FTNI, and BTNI because they represent either > 3.5% but < 20 % of the total peatland area or > 2% but < 20 % of the total number of polygons. If the peatland type is intermediate in rarity go to the right (y); if not, go to the left (n) .

3) All rare peatland types should be conserved because they represent only a small portion (< 3.5 % area) of the total peatland types. Four of the 8 peatland types have permafrost present, 1 has internal lawns, 2 are patterned, and 1 type is graminoid dominated. The significance of permafrost, and peatland ecology in general, are discussed Chapter 2 (MSc thesis, Forest, 2000).

Rare peatland types should be identified in the GIS data base to conserve them.

4) Peatlands identified as caribou habitat by the Boreal Caribou Committee should be conserved so that the habitat is maintained. The Alberta Government issued an information letter (IL 91-17) that states that industrial activity can continue on caribou range "providing the integrity of the habitat is maintained to support its use by caribou" (Alberta Energy, 1991). Horticultural peat harvesting or removal of vegetation for other purposes does alter peatland ecology and affect habitat and habitat quality. Contact

the BCC for management recommendations, also see decision 7.

5) Peatlands that have </= 2% linear (or other anthropogenic) disturbance per polygon should be conserved. Linear disturbance here is calculated without buffers. Most peatlands in boreal Alberta have been impacted by seismic exploration (> 1,800 km of linear disturbance in the peatlands within the study area) and to only select pristine peatlands would probably exclude too many peatlands from protection. If the peatlands have =/< 2% disturbance conserve; if > 2 % disturbance go to 8. The percent disturbance per peatland polygon must be obtained from the GIS data base; it was not available at the time of the study. However, a small subsample of approximately 2% of polygons suggested a 2% cut-off. If disturbance per polygon is =/< 2% go to the left (y), conserve; if > 2% go to the right (n), decision 8.

6) as above - if yes, conserve; if no, go to 9.

7) The BCC, in consultation with the peat industry, is in the process of developing management recommendations for peatlands within caribou range. Contact the BCC for details and possible management suggestions.

8) Peatlands that provide habitat for rare, threatened, or endangered organisms, have a potentially high species diversity, have an established research history, or have potential as future research sites should be conserved. **A site visit is necessary to assess species rarity and diversity.** If the sites have rare species or a high species diversity, the peatland polygon should be identified on the GIS data base and rare species should be reported to ANHIC (flora) or Alberta Fish and Wildlife (fauna).

Permafrost sites (present or former permafrost) may be important research sites in respect to changing climate studies.

9) as in 8)

10) Not all of the identified sites or peatland types are suitable for peat harvesting. At this couplet (decision point), sites with high ecological and/or research values are excluded from potential harvesting sites. All peatland types that are identified following the decision key should belong to one of the following peatland types: BTNR, FONS, FTNI, and BTNI. Such peatland types are generally not the preferred peatland types for horticultural peat harvesting.

11) Unlike in decision 10 above, peatland types that are identified here are common and only include FTNN and BTNN. Bogs,

BTNN, have the desired weakly decomposed *Sphagnum fuscum* peat and are easily identified on the GIS data base or the hard copy maps. Treed fens on the other hand range from poor fens to intermediate rich (in the study area, may be extreme rich in other areas in Alberta) but only poor fens provide *S. fuscum* peat. All treed fens are mapped as FTNN and it is not possible to identify horticultural peat harvesting potential in the GIS data base or the maps. Poor fens can be easily and quickly identified on ground.

12) Conserve the peatlands and identify in the GIS peatland layer data base as conserved. If rare species are present, notify applicable authority: ANHIC for flora and Alberta Fish and Wildlife for fauna. Sites with research history and/or research potential should be identified in the data base for long term management planning.
13) Peatlands not suitable for development should be identified for conservation; surface area and number of polygons per type and overall should be calculated. Peatlands identified for conservation or development must be included in a proper management plan.

14) as above in 13).

15) Peatlands that have been identified as having harvesting potential should be identified in the GIS data base for long term management plans. Calculate the amount of peatland of the selected sites (identified polygons that meet conditions b - d). The total area and the total number of polygons, as well as area and the number of polygons per peatland type, their geographic locations within Alberta's subregions and within the study area, should be assessed. Please note, subregion boundaries were not overlain on the peatland layer and were not available at the time of the study but it is recommended.

Once the amount of peatland that met conditions b - e is calculated, answer question 15. The cutoff is 45% in relation to either peatland surface area or to the number of polygons per peatland type, whichever is higher. Forty-five percent is an arbitrary number chosen, see Chapter 2 (MSc thesis, Forest, 2000).

If > 45% per peatland type are identified, the conditions under 15) have to be applied more stringently; e.g. sites should be closer to roads or sites have to have a larger degree of disturbance. GIS analysis should be applied to answer question 15 efficiently and reliably.

16) Sites that are found suitable by the above process and are desired by industry should be assessed on ground for rare fauna and/or flora by a professional biologist. Other assessments such as EIA or CEA are not discussed in this document.

Peatlands that have been identified as having horticultural peat harvesting potential have not been checked for peat volumes or quality. The selection process only addressed the separation of the most ecological valued peatlands from those that are less

valued under the criteria and methods introduced earlier in the document.

17) See 15).

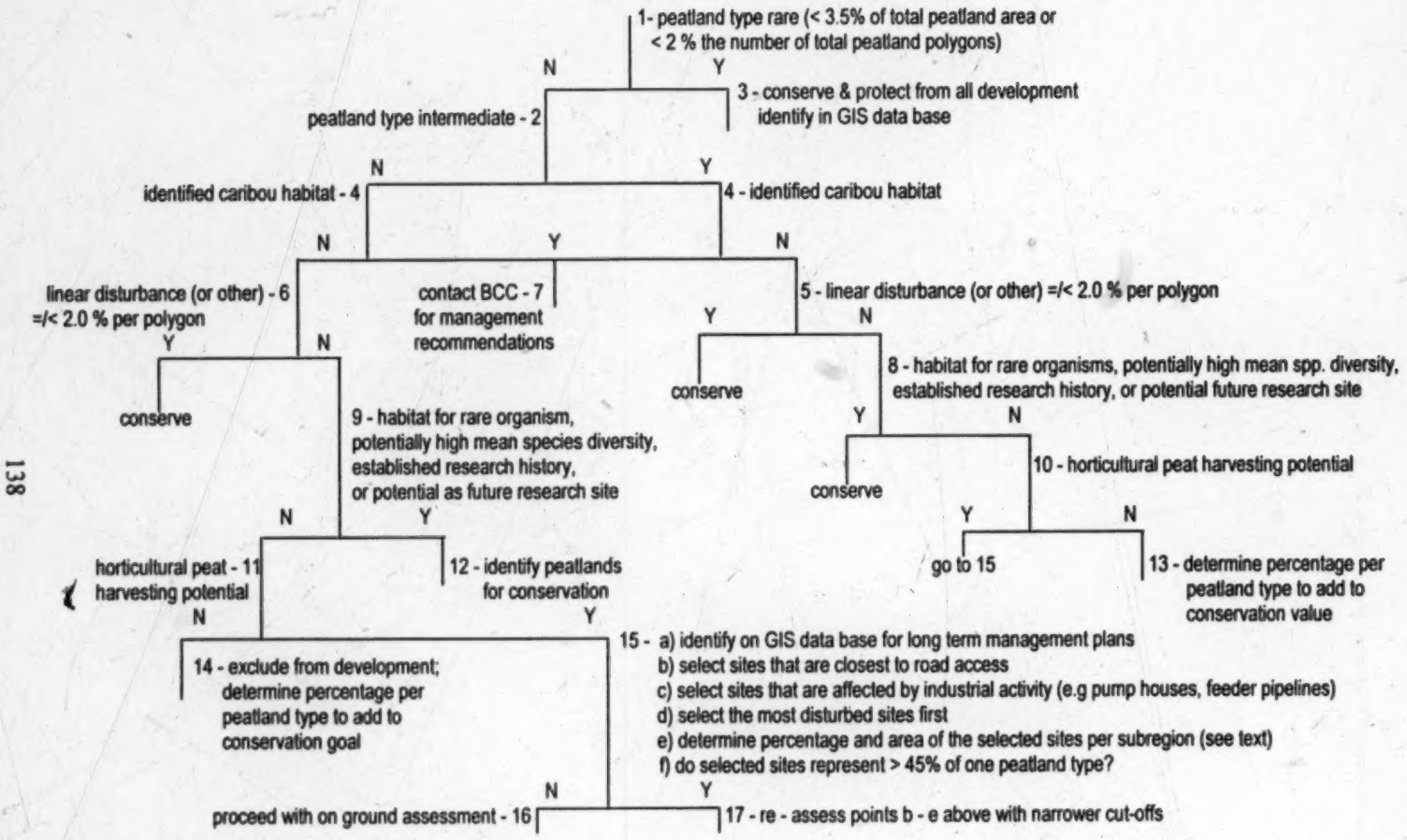

Figure 4.3. Peatland Management Decision Key. See text Table 4.4.

Peatland Conservation Goals

In 1991 the Canadian Environmental Advisory Council recommended that large areas in the order of 4,000 km^2 are needed for complete wilderness and biodiversity protection. It is not clear which percentage of peatlands should be conserved, but it is clear that industrial development in Alberta is proceeding at an enormous rate and that industry is leaving a large ecological footprint behind. At the landscape level, peatlands should be conserved by AWI peatland types within the framework of their rarity ratings.

Peatlands that were identified as rare in the AWI inventory (see Table 4.2 in result section) represent < 2% (94 km^2) of all peatlands (by area) and < 1% of the entire study area. Rare peatlands should be excluded from peat extractions (horticultural or fuel peat), drainage for cattle grazing or forestry, or habitat fragmentation (e.g. seismic exploration, pipelines, surface disturbance of in-situ operations) because only if these rare peatlands are protected can one ensure adequate representation of Alberta's natural diversity.

Peatlands that were identified as intermediate in rarity represent 16% of the entire study area and 55% of these peatlands should be conserved as natural representatives of the landscape. Selection of the protected sites should be by the criteria listed in the decision key. Intermediate rare peatland types that have </= 2% disturbance, or provide habitats for rare organisms, have a potentially high species diversity, have an established research history, and/or potential as future research sites (determined by research objective - if the research objective is site disturbance, other sites can be selected) should be selected as conservation candidates. Fifty-five percent of the intermediate peatland types represent < 9% of the study area and should be identified for conservation (Table 4.5).

Common peatland types (treed bogs and fens) represent 57% of all peatlands within the study area and cover 2835 km^2 of which 1362 km^2 are bogs (Table 4.5). Economic development by horticultural peat industry would not be curtailed by imposing a 55% peatland conservation goal but would still leave > 600 km^2 of bogs unprotected. In the green area 1,800 ha are currently developed by horticultural peat industry, and companies generally stay on one site for 20-30 years (Tony Cable, pers. com.).

Table 4.5. Recommendation overview for proposed peatland conservation percentages and land areas within the study area. The protected peatland area represents 22% of the entire study area but does not protect 2185 sq. km from development.

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	rare peatlands	intermediate peatlands	common peatlands	of total peatlands	peatlands not protected
recommended % protection	100%	55%	55%	56%	44% - leaving 2185 sq. km of peatlands unprotected. Of the above peatlands, > 600 sq. km are bogs - the peatland type preferred by horticultural peat companies.
total peatland area conserved (sq. km)	94	1121	1561	2776	
total peatland area (sq. km)	94	2038	2835	4967	Presently only one company exists within the green area and operates on a site of 1,800 ha - the equivalent of almost 3% of all the bogs within the study area.
% of entire study area	< 1%	16%	23%	40%	Horticultural peat harvesting would not be impacted by the management recommendation but oil and gas exploration and possibly forestry would have to change their field operations and planning.

PEATLAND MANAGEMENT RECOMMENDATIONS

Peatland Management Areas

Peatland management areas should be chosen within the ecological framework of Alberta's Natural Regions and Subregions (Achuff, 1994). These regions were identified based on biophysical attributes that more than likely affect ecological peatland type distribution and type of animal and plant species distribution. The ecological framework and boundaries already exists and adoption of Natural Subregions boundaries as Peatland Management Areas (PMA) would probably be easy and effective.

Peat Mining for Fuel Peat

It is strongly recommend that no approval will be given for fuel-peat mining. The amount of peat mined would not only quickly devastate large peatland area but also affect hydrology and ecological integrity of the surrounding land. Peat has a relatively low heat content compared to coal and it would not be productive to mine fuel peat considering the amount of coal deposists in Alberta. Calorific values of peat are 3,000 kcal/kg (5,400 Btu/lb) compared to hard coal (bituminous or anthracite) that has a calorific values of 8,650 kcla/kg (15,500 Btu/lb) (Craig et al., 1988).

Applicability of Peatland Management Key for the Green Area

The management key was developed with data from a 12,556 km^2 study area. The area was chosen because of its high peatland density (40% or almost 5,000 km^2 of peatlands) and is not representative of the entire green area. It is my recommendation to test the applicability to all Natural Subregions, especially in the foothills where peatlands are less frequent and ecologically different. Ecological and management issues may be very specific in a given Subregion and it is important to incorporate such local needs.

Cumulative Effects Models as Aid in Landscape Management

Alberta's Boreal Forest provides many economic opportunities and wealth to

Albertans but the ecological health and balance between economy and ecology is also of great importance. Because of the various industries and their ecological foot print and the various ecological concerns, often species specific, land management becomes a difficult task.

Linear disturbance features not only fragment habitats but also create an edge effect that may allow for invasive species to establish themselves, infiltrate the peatland matrix for a distance from the edge, and change the microclimate, and species assemblage and movement. In addition, seismic lines also affect hydrology (Fig. 4.4) because of peat compaction. Seismic lines are lower than the surrounding peatland surface (can be 15-20 cm or more, pers. obs.) and act as drainage channels. They can drain water from peatlands and channel it in the direction of the natural water flow (pers. obs.). In some instances, vegetation typical of marshes (e.g. *Cicuta maculata*) has been observed on seismic lines cut through treed fens (pers. obs.).

Impact of natural resource industries such as oil and gas or forestry can be identified on aerial photographs such as in Figure 4.5. Although forestry companies are currently not harvesting timber in peatlands, their operations can be in close proximity to peatlands and, thus affect peatlands.

Forem Consulting developed a commutative effects model (ALCES - Alberta Landscape Cumulative Effects Simulator) for Alberta to assess cumulative effects on the landscape level. Such a model may be used to manage peatlands separate from other lands, or manage the landscape as the mosaic it represents (from upland to water bodies). Dr. Brad Stelfox Forem Consulting, can be contacted at 408-949-3008.

Applied On-ground Wetland Ecosystem Classification for the Green Area

Although peatlands have been classified based on richness (in nutrients or species richness) in Alberta (Vitt et al., 1995; Vitt & Chee, 1990; Chee & Vitt, 1989) an applied on-ground wetland ecosystem classification does not exists. Especially a classification that allows for:

a) site classification by indicator species, flooding regime, percent vegetation cover, and

Fig. 4.4. Cutline through a peatland in northeastern Alberta.

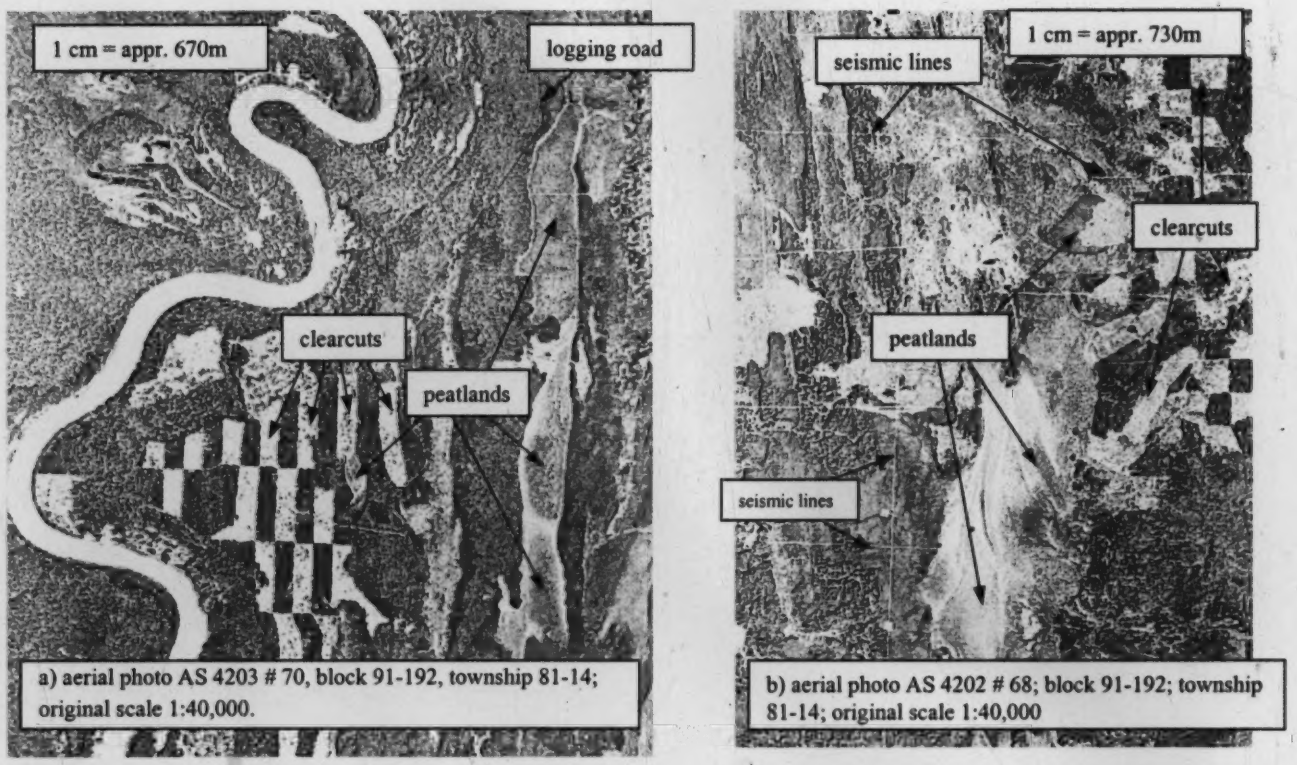

Fig. 4.5. The above aerial photographs show how industries such as forestry and oil and gas operate in, or in close proximity of, peatlands. Peatlands can not be managed as isolated entities but cumulative effects of industry, in addition to species habitat and movement, must be taken into consideration.

substrate at the local level;

b) wetland information and gathering (at the local level);

c) identification and classification of species habitat (e.g. waterfowl; rare species habitat, e.g. *Sarracenia pupurea* - the Northern Pitcher Plant; fish spawning habitat; staging areas for migrating birds such as cranes; amphibian habitat; for conservation groups such as Ducks Unlimited, or possible others);

d) usage of a common language when describing wetland communities (a concrete wetland type identified by a letter/number system that describes an ecological community, e.g. open graminoid shore fen/wire sedge dominated) - biologist other than wetland ecologists or engineers often use wetland terms loosely (terms such as *muskeg, swamp*, or *marsh* are often used interchangeably when indeed they describe very different ecological communities); and

e) site assessment prior to industrial development and the creation of the same habitat type elsewhere.

Overall, the importance of an applied on-ground wetland ecosites classification is that it "provides a common language and framework to facilitate communication of scientific information and management techniques among resource managers" (Harris et al., 1996).

Figure 4.6 shows an oblique photograph of a peatland that was mapped in this project as an open, patterned fen with internal lawns (FOPI) under AWI Standards. If a ground survey would be conducted, several different ecological communities would be identified but under the AWI they are lumped together. Further, not all internal lawns appear to be the same age and can probably have various moisture levels and associated species (D. Beilman, pers. com). An on-ground wetland classification would allow for the identification of all the habitats shown in Figure 4.6.

Identification of Peatland Type Status

A peatland type's status of rare, intermediate, or common should be identified in the GIS data base before other management plans are made. Once identified, peatland

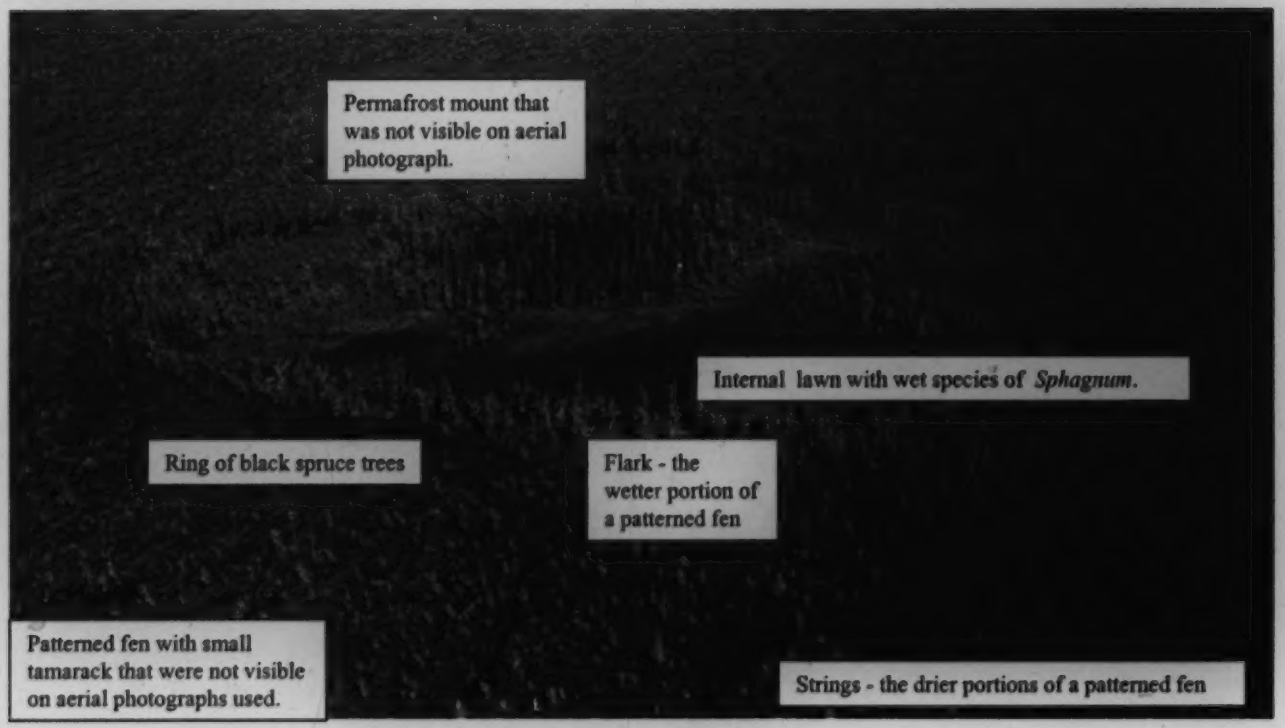

Fig. 4.6. Oblique photograph of a peatland that was mapped as an open patterned fen with internal lawns (FOPI). On ground, ecological communities can be differentiated at a finer scale and used in species habitat descriptions for rare species surveys or site assessments.

users such as horticultural peat or hydrocarbon industries can operate within the framework of peatland management goals. For example, if all rare peatlands are protected from development and industry is made aware of the status **prior** to developing a business plan, industry has the opportunity to avoid such areas. It makes good business sense to be aware of potential 'show stoppers' before the fact and possibly save time and money.

Updated Data Bases

To manage peatlands properly, data bases must be updated frequently. While natural peatlands or peatland types do not change quickly if their ecological integrity is not jeopardized, anthropogenic disturbance and its impact does. Disturbance in peatlands should be monitored to understand rate of disturbance and possible effects.

Identification of Peatland Caribou Use/ Cooperation with BCC

Identification of caribou habitat in the GIS data base would serve the same purpose as above. Identification of caribou habitat and management recommendations should come from the Boreal Caribou Committee. "The BCC represents industrial users and provincial government land and wildlife managers...with the goal to integrate industrial activities in northern Alberta with the management and conservation of caribou and caribou habitat....results and research [of the BCC] are used by provincial regulatory agencies to develop and implement effective and practical landuse guidelines." (Boreal Caribou Committee, 2000). It would be beneficial to all parties involved to have a strong working relationship in respect to peatland management.

Cooperation with the Natural Resources Industries

Natural Resources Industries that should be targeted are conventional oil and gas, forestry and tar sands industry (the latter one especially once 1:50,000 peatland maps are available for the tar sands region). The goal is to keep all industries informed of peatlands that should be protected (e.g. because the peatland is rare, has rare species, was

selected to be a representative site under a protected areas program) and be informed by industry of their proposed developments if peatlands in question are affected.

Cooperation with ANHIC and Alberta Fish and Wildlife

Both of the above provincial government departments are involved in rare species tracking and it is essential that such agencies are involved in peatland management. The agencies may identify where rare species are and propose what action should be taken.

Protected Areas Management

Within the framework of the provincial government, parks, wilderness areas, and special places 2000 areas are managed. Selection of peatlands for protection could be made within a larger framework and representatives sites could be selected and identified under already existing programs and thus enlarging contiguous habitats that represent the natural landscape.

Cooperation with Research Institutions

Research institutions such as the University of Alberta have been involved in peatland research and contributed to our present knowledge of peatland ecology. Continuing corporation, especially identification of gaps of knowledge and establishment of long-term research sites, would be beneficial. For example **research relating to cutline reclamation in peatlands, impact of cutlines in respect to peatland hydrology, and impact of cutlines to plant species distribution is needed.** Presently we have no empirical data that demonstrates the above. We do have data that demonstrates that cutlines affect woodland caribou (Dyer, 1999) and that woodland caribou prefer treed peatlands over other habitat classes (Anderson, 1999).

PEATLAND MANAGEMENT - BENEFITS TO INDUSTRY

The ecological peatland management key, a future ecological on-ground wetland ecosystem classification system, and resource maps may benefit industry in various ways. Resource industry may be able to identify ecologically sensitive areas while planning and thus possibly avoid costly and time consuming delays, and can possibly demonstrate good ecological management.

Other industries such as ecotourism may also benefit from the above. This may be especially true for smaller communities where employment opportunities are limited and birdwatching, botanizing, and or other nature experiences can be offered to tourists. Perhaps currently not a large industry in northeastern Alberta but certainly not one that should be ignored.

Horticultural Peat Industry:

Horticultural peat companies may benefit from the ecological peatland management key and/or an on-ground wetland ecosystem classification in the following ways. They may reduce or eliminate costly environmental assessments when selecting sites because rare peatlands at the landscape level were already identified and rare on-ground peatland types can be identified easier with an applied on-ground ecological wetland classification system. Rare species habitats can potentially be identified with on-ground wetland classification and possibly make rare plant surveys more efficient. A peatland's location and type (from resource maps) can easily be identified and caribou presence/absence and/or critical caribou habitat can be identified by the Boreal Caribou Committee. The committee should make management suggestions to avoid future land use conflicts. A horticultural peat mining company's cooperation with the hydrocarbon industry may reduce initial investments for road building and/or peatland drainage by identifying sites that are already impacted and/or have road access.

Conventional Oil and Gas Industry:

The hydrocarbon industry may benefit by demonstrating in their application for new seismic lines, well sites, or pipeline that they are taking rare peatlands or rare peatland habitat (for rare/threatened or endangered species) in consideration and are avoiding such areas.

Tar Sand Industry:

Although the tar sands area within the Regional Municipality of Wood Buffalo lies just north-east of the study area and was not inventoried, future inventories may benefit tar sands operations. Identification of existing wetlands can be used to a) identify peat deposits that are crucial for site reclamation and soil amendments, and b) use existing wetlands for recycling water on site. Both, locating organic soils and using wetlands to recycle process water on site, are current issues in reclamation at Suncor (S. Tuttle, pers.com.) and Syncrude (E. Anderson, pers. com.).

Forestry:

Although the forest industry in Alberta is currently not harvesting trees on peatlands, part of the forest industry's responsibility (in conjunction with other regulators) is wildlife management. Some species, especially caribou but perhaps also martens or other mustelid, not only inhabit peatlands but also forested lands. Forestry companies may be able to plan better for wildlife management by utilizing peatland inventories (or the total wetland layer) in addition to the Alberta Vegetation Inventories. Figure 4.5 shows that forestry companies can operate in close proximity to peatlands.

Alberta Environment:

Within the frame work of Alberta Environment the Alberta Natural Heritage Information Centre and Fish and Wildlife may be able to use the peatland resource maps and the proposed on-ground wetland ecosystem classification for rare species tracking. The peatland inventory (or total wetland inventory) can be used in its digital format to

track species sightings, identify crucial habitat, and inform industry of sensitive sites.

On-ground classification can be used to describe rare species habitat and species data can become more meaningful in that habitat can now be identified in concrete terms and references rather than using descriptions such as *swampy* or *boggy*.

Summary Statement:

It is clear that present horticultural peat extractions alone are not the primary concern in peatland management but rather the combined effect of natural resource industry. The hydrocarbon industry leaves the largest footprint in Alberta at this time, but as peat companies move farther north and expand, their impact must be taken into consideration as well. It is important not to deplete bogs close to transportation routes in the southern portion of the green area, otherwise ecological representation of the landscape can not be sustained.

Overall, the total recommended area for conservation within the study area is 22%, but a) it must be remembered that the area was chosen because of its abundance of peat, and b) that peatlands may be managed as different geographic units in the future. The study area does not correspond to a Natural Subregion that is identified by its biophysical attributes but is identified by township boundaries. It would be ecologically meaningful to adopt Natural Subregions as peatland management regions.

Most regions outside the study area but within the green area have fewer peatlands and conservation recommendations, especially the amount of peatlands that should be conserved, would be lower. Thus, the percentage of peatland that is protected within the study area can not be used to extrapolate the amount of peatland that would be conserved in the entire green area. Regions outside the study area have often considerable fewer peatlands, this is especially true for the Foothills Natural Region where peatlands represent < 8% of the entire landscape (Vitt et al., 1996) compared to the study area where peatlands represent 40% of the landscape.

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Appendix A. Species list of all vascular plants, bryophytes and lichens in alphabetical order by genus, followed by the author. A total of 255 species were identified.

Abies balsamea (L.) Mill.
Adoxa moschatellina L.
Alnus rugosa (Du Roi.) Spreng.
Amblystegium serpens (Hedw.) Schimp.
Anastrophyllum minutum (Schreb.) Schuster
Andromeda polyfolia L.
Aneura pinguis (L.) Dum.
Aulacomnium palustre (Hedw.) Schwaegr.
Betula glandulosa Michx.
Betula papyrifera Marsh.
Blephorostoma trichophyllum (L.) Dumort.
Brachythecium erythrorrhizon Schimp.
Brachythecium mildeanum (Schimp.) Schimp. ex Milde
Brachythecium salebrosum (Web. & Mohr) Schimp.
Brachythecium turgidum (Hartm.) Kindb.
Bryum pseudotriquetrum (Hedw.) Gaertn. et al.
Calamagrostis candadensis (Michx.) Beauv.
Calla palustris L.
Calliergon giganteum (Schimp.) Kindb.
Calliergon obtusifolium Karcz.
Calliergon richardsonii (Mitt.) Kindb.
Calliergon stramineum (Brid.) Kindb.
Calypogeia sphagnicola (Arn. & Perss.) Warnstf. & Loeske
Campanula aparinoides Pursh
Campylium stellatum (Hedw.) C. Jens
Campylium chrysophyllum (Brid.) C. Jens
Carex aquatilis Wahlenb.
Carex brunnescens (Pers.) Poir
Carex curta Good.
Carex chordorrhiza L.f.
Carex diandra Schrank
Carex disperma Dewey
Carex gynocrates Wormsk.
Carex interior Bailey
Carex lacustris Willd.
Carex lasiocarpa Ehrh.
Carex limosa L.
Carex paupercula Michx.
Carex pauciflora Lighf.
Carex prairea Dewey

Carex rostrata Stokes
Carex tenuiflora Wahlenb.
Carex trisperma Dewey
Cephalozia bicuspidata (L.) Dumort.
Cephalozia connivens (Dicks.) Spruce
Cephalozia loitlesbergeri Schiffn.
Cephalozia lunulifolia (Dum.) Dum.
Cephalozia macrostachya Kaalaas
Cephalozia pleniceps (Aust.) Lindb.
Cephaloziella byssacea (Roth) Warnstf.
Cephaloziella hampeana (Nees.) Schiffn.
Cephaloziella spinigeria E. Jörgenson
Ceratodon purpureus (Hedw.) Brid.
Cetraria nivalis (L.) Ach.
Chamaedaphne calyculata (L.) Moench
Cicuta maculata L.
Cinclidium stygium Sw.
Cladina mitis (Sandst.) Hustich
Cladina rangiferina (L.) Nyl.
Cladina stellaris (Opiz) Brodo
Cladonia species Hill ex Browne
Cladopodiella fluitans (Nees) Buch
Climacium dendroides (Hedw.) Web. & Mohr
Corallorhiza trifida Châtelain
Cornus canadensis L.
Cornus stolonifera Michx.
Dicranum fragilifolium Lindb.
Dicranum fuscescens Turn.
Dicranum polysetum Sw.
Dicranum scoparium Hedw.
Dicranum undulatum Brid
Conocephalum conicum L. Lindb.
Drepanocladus aduncus (B.S.G.) Monk.
Drepanocladus exannulatus (B.S.G.) Warnst.
Drepanocladus fluitans (Hedw.) Warnst.
Drepanocladus lapponicus (Norrl.) Smirn.
Drepanocladus revolvens (Sw.) Warnst.
Drepanocladus uncinatus (Hedw.) Warnst.
Drepanocladus vernicosus (Lind. ex C. Hartman) Warnst.
Drosera anglica Huds.
Drosera linearis Goldie
Drosera rotundifolia L.
Dryopteris carthusiana (Vill.) H.P. Fuchs

Empetrum nigrum L.
Epilobium angustifolium L.
Epilobium ciliatum Raf.
Epilobium palustre L.
Equisetum arvense L.
Equisetum fluviatile L.
Equisetum palustre L.
Equisetum scirpoides Michx.
Equisetum sylvaticum L.
Eriophorum chamissonis C.A. Mey.
Eriophorum polystachion L.
Eriophorum brachyantherum Trautv.
Eriophorum gracile Koch
Eriophorum vaginatum L.
Eriophorum viridi-carinatum Engelm. Fern.
Eurhynchium pulchellum (Hedw.) Jenn.
Frageria virginiana Duchesne
Galium labradoricum Wieg.
Galium trifidum L.
Galium triflorum Michx.
Gaultheria hispidula (L.) Bigel.
Geocalyx graveolans (Schrad.) Nees
Geocaulon lividum (Richards.) Fern.
Geum rivale L.
Glyceria pulchella (Nash) K. Schum.
Habenaria dilatata (Pursh) Hook.
Habenaria hyperborea (L.) Lindl.
Habenaria viridis (L.) R. Br.
Helodium blandowii Web. & Mohr Warnst.
Herzogiella turfacea (Lindb.) Iwats.
Hippuris vulgaris L.
Hylocomnium splendens (Hedw.) Schimp.
Hypnum lindbergii Mitt.
Hypnum pratense (Rabenh.) W. Koch ex Spruce
Icmadophila ericetorum (L.) Zahlbr.
Juncus bufonicus L.
Kalmia polifolia Wang.
Larix laricina (Du Roi) K. Koch
Ledum groenlandicum Oeder
Ledum palustre L.
Lemna minor L.
Lemna trisulca L.
Lepidozia repens reptans (L.) Dumort.

Leptodictyum riparium (Hedw.) Warnst.
Linnea borealis L.
Listera cordata (L.) R.Br.
Lonicera involucrata (Richards.) Banks
Lonicera caerula Michx.
Lophocolea heterophylla (Schrad.) Dumort.
Lophozia species Dumort.
Lycopodium annotinum L.
Lysimachia thyrsiflora L.
Maianthemum canadense Desf.
Marchantia polymorpha L.
Meesia triquetra (Richt.) Angst.
Meesia uliginosa Hedw.
Menyanthes trifoliata L.
Mitella nuda L.
Mylia anomala (Hook.) Gray
Myrica gale L.
Myurella julacea (Schwaegr.) Schimp.
Orchis rotundifolia Banks ex Pursh
Pedicularis groenlandica Retz.
Pedicularis labradorica Wirsing
Pedicularis parviflora J.E. Smith
Peltigera aphthosa (L.) Willd.
Peltigera canina (L.) Willd.
Peltigera malacea (Ach.) Funck
Peltigera membranacea (Ach.) Nyl.
Peltigera neopolydactyla (Gyelnik) Gyelnik
Peltigera scabrosa Th. Fr.
Petasitis palmatus (Ait.) A.Gray L. Fries
Petasitis sagittatus (Pursh) A. Gray
Phragmitis australis (Cav.) Trin. ex Steud.
Picea glauca (Moench) Voss
Picea mariana (Mill.) BSP.
Pinguicula vulgaris L.
Pinus banksiana Lamb.
Plagiochila porelloides (L.) Dumort.
Plagiomnium cuspidatum (Hedw.) T. Kop.
Plagiomnium drummondii (Bruch & Schimp.) T. Kop.
Plagiomnium ellipticum (Brid.) T. Kop.
Plagiomnium medium (Bruch & Schimp.) T. Kop.
Plagiothecium denticulatum (Hedw.) Schimp.
Pleurozium schreberi (Brid.) Mitt.
Poa palustris L.

Poa pratensis L.
Pohlia nutans (Hedw.) Lindb.
Pohlia sphagnicola (Bruch & Schimp.) Lind. & Arnell
Politrichum commune Hedw.
Polygonum coccineum Muhl.
Polytrichum juniperinum Hedw.
Polytrichum strictum Brid.
Potamogeton gramineus L.
Potentilla palustris (L.) Scop.
Pseudobryum cinclidioides (Hüb.) T. Kop.
Ptilidium ciliare (L.) Nees
Ptilidium pulcherrimum (Web.) Hampe
Ptilium crista-castrensis (Hedw.) De Not.
Pyrola asarifolia Michx.
Pyrola chlorantha Sw.
Ranunculus gmelinii DC.
Ranunculus lapponicus L.
Rhinanthus borealis (Sterneck) Chab.
Rhizomnium gracile T.Kop.
Rhizomnium pseudopunctatum (Hedw.) Kop.
Rhyncospora alba (L.) Wahl.
Ribes glandulosum Grauer
Ribes hirtellum Michx.
Ribes hudsonianum Richards.
Ribes oxyacanthoides L.
Riccardia latifrons (Lindb.) Lindb.
Rosa acicularis Lindl.
Rubus arcticus L.
Rubus chamaemorus L.
Rubus idaeus L.
Rubus pubescens Raf.
Rumex species L.
Salix bebbiana Sarg.
Salix candida Fluegge ex Willd.
Salix discolor Muhl.
Salix maccalliana Rowlee
Salix pedicellaris Pursh
Salix planifolia Pursh
Salix pyrifolia Anderss.
Sarracenia pupurea L.
Scapania irrigua (Nees) Dumort.
Scheuchzeria palustris L.
Scorpidium scorpioides (Hedw.) Limpr.

Scutellaria galericulata L.
Sium suave Walt.
Smilacena trifolia (L.) Desf.
Sphagnum angustifolium (C. Jens. ex Russ.) C.Jens.
Sphagnum centrale C. Jens.
Sphagnum contortum Schulz
Sphagnum fimbriatum Wils.
Sphagnum fuscum (Schimper.) Klinggr.
Sphagnum lindbergii Schimp.
Sphagnum magellanicum Brid.
Sphagnum majus (Russ.) C. Jens.
Sphagnum capillifolium (Ehrh.) Hedw.
Sphagnum obtusum Warnst.
Sphagnum riparium Ångstr.
Sphagnum russowii Warnst.
Sphagnum squarrosum Crome
Sphagnum subsecundum Nees
Sphagnum teres (Schimp.) Ångstr.
Sphagnum warnstroffii Russ.
Sphagnum wulfianum Girg.
Spiranthes romanzoffiana Cham.& Schlecht.
Spirodela polyrhiza (L.) Schleiden
Stellaria crassifolia Ehrh.
Stellaria longifolia Muhl.
Tetraplodon angustatus (Hedw.) Bruch & Schimp.
Tetraplodon mnioides (Hedw.) Bruch & Schimp.
Thuidium recognitum (Hedw.) Lindb.
Tofieldia glutinosa (Michx.) Pers.
Tomenthypnum falcifolium (Ren. ex Nichols) Tuom.
Tomenthypnum nitens (Hedw.) Loeske
Trifolium repens L.
Triglochin maritima L.
Typha latifolia L.
Urtica dioica L.
Utricularia minor L.
Utricularia vulgaris L.
Utricularia intermedia Hayne
Vaccinium myrtilloides Michx.
Vaccinium oxycoccos L.
Vaccinium vitis-idaea L.
Vibernum edule (Michx.) Raf.
Viburnum trilobum (March) Clausen
Viola species L.